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(71) Applicant: ABBOTT LABORATORIES
Abbott Park Illinois 60064(US)

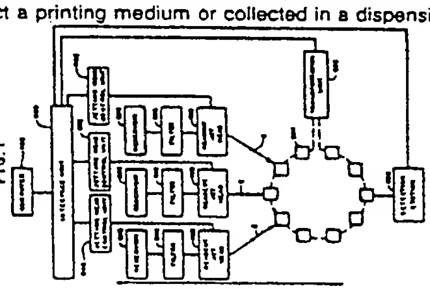
(72) Inventor: Hayes, Donald J.
2012 Tampicko Drive
Plano Texas 75075(US)
Inventor: Wallace, David B.
9929 Wood Forest
Dallas Texas 75243(US)
Inventor: Verlee, Donald J.
563 Drake Street
Libertyville Illinois 60048(US)
Inventor: Houseman, Kenneth R.
1520 S. Main Street
Racine Wisconsin 53403(US)

(74) Representative: Modiano, Guido et al
MODIANO, JOSIF, PISANTY & STAUB
Modiano & Associati Via Meravigli, 16
I-20123 Milan(IT)

(54) Apparatus and process for reagent fluid dispensing and printing.

(57) A system for printing and dispensing chemical reagents in precisely controlled volumes onto a medium at a precisely controlled location. A jetting tube, comprising an orifice at one end and a fluid receiving aperture at the other end, is concentrically mounted within a cylindrical piezo-electric transducer. The fluid receiving aperture is connected to a reservoir containing a selected reagent by means of a filter. The reservoir is pressurized by a regulated air supply. An electrical signal of short duration is applied to the transducer. The pulse causes the transducer and the volume defined by the jetting tube to expand, thereby drawing in a small quantity of reagent fluid. The cessation of the pulse causes the transducer and the volume of the jetting tube to de-expand, thereby causing at least a substantially uniformly sized droplet of reagent fluid to be propelled through the orifice. The droplet may be directed to impact a printing medium or collected in a dispensing recepticle.

FIG.1



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APPARATUS AND PROCESS FOR REAGENT FLUID DISPENSING AND PRINTING

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus and process for dispensing and printing reagent fluids, wherein a transducer is used to propel small quantities of the fluid towards a positioned target.

Diagnostic assays often require systems for metering, dispensing and printing reagent fluids. In the case of metering and dispensing, such systems comprise both manual and automatic means. For purposes of practicality, the present background discussion will focus on the methods of metering and dispensing 100 micro-liter volumes or less.

The manual systems of metering and dispensing include the glass capillary pipet; the micro-pipet; the precision syringe; and weighing instruments. The glass capillary pipet is formed from a precision bore glass capillary tube. The pipet typically comprises a fire blown bulb and a tubular portion fire drawn to a fine point. Fluid is precisely metered by aspirating liquid through the tube into the bulb to a predetermined level indicated by an etched mark. The fluid may then be dispensed by blowing air through the tube.

The micro-pipet typically comprises a cylinder and a spring loaded piston. The travel of the piston is precisely determined by a threaded stop. The distance the piston travels within the cylinder and the diameter of the cylinder define a precise volume. The fluid is aspirated into and dispensed from the micro-pipet in precise quantities by movement of the piston within the cylinder.

The precision syringe generally comprises a precisely manufactured plunger and cylinder with accurately positioned metering marks. The fluid is introduced into and dispensed from the syringe by movement of the plunger between the marks.

Weighing techniques for dispensing fluids often simply involve weighing a quantity of fluid. The density of the fluid may then be used to determine the fluid volume.

Exemplary automatic metering and dispensing systems include the precision syringe pump; the peristaltic pump; and the high performance liquid chromatography (HPLC) metering valve. The precision syringe pump generally comprises a precision ground piston located within a precision bore cylinder. The piston is moved within the cylinder in precise increments by a stepping motor.

The peristaltic pump comprises an elastomeric tube which is sequentially pinched by a series of rollers. Often the tube is placed inside a semi-circular channel and the rollers mounted on the outer edge of a disc driven by a stepping motor. The movement of the rollers against the tubing produces peristaltic movement of the fluid.

The HPLC metering valve comprises a defined length of precision inner diameter tubing. The fluid is introduced into the define volume of the tubing with the valve in a first position and then dispensed from the tubing when the valve is placed in a second position.

All of the above metering and dispensing systems have the disadvantage that the volumes dispensed are relatively large. Furthermore, these systems are also relatively slow, inefficient and comprise precision fitted components which are particularly susceptible to wear.

The printing of reagent fluids is frequently required in the manufacture of chemical assay test strips. Selected reagents are printed in a desired configuration on strips of filter paper. The strips may then be used as a disposable diagnostic tool to determine the presence or absence of a variety of chemical components.

Generally, to perform a chemical assay with a test strip, the strip is exposed to a fluid or a series of fluids to be tested, such as blood, serum or urine. In some instances, the strip is rinsed and processed with additional reagents prior to being interpreted. The precise interpretation depends on the type of chemical reactions involved, but it may be as simple as visually inspecting the test strip for a particular color change.

The manufacture of test strips generally involves either a manufacturing process or a blotting process. The blotting process is the simplest manufacturing method and permits most reagents to be applied without modification. A disadvantage of this process is that it is difficult to blot the fluids onto the test strip with precision.

The printing process will often involve any of three well known methods: silk screening; gravure; and transfer printing. The silk screening of reagents generally involves producing a screen by photographic methods in the desired configuration for each reagent to be printed. The screen is exposed under light to a preselected pattern and then developed. The areas of the screen which are not exposed to light, when devel oped, become porous. However, the areas of the screen which have been exposed to light remain relatively nonporous. The screen is then secured in a frame and the test strip placed below. The desired

reagent fluid, specially prepared to have a high viscosity, is spread over the top side of the screen. The reagent passes through the porous areas of the screen and onto the test strip. The test strip is then subjected to a drying process, specific to each reagent. Once the test strip is dry, it may be printed again using a different screen, pattern and reagent.

The gravure method of printing reagents comprises coating a metal surface with a light sensitive polymer. The polymer is exposed to light in the desired predetermined pattern. When developed, the polymer creates hydrophilic and hydrophobic regions. The reagent is specially prepared such that when applied to the metal it will adhere only to the hydrophilic regions. After the specially prepared reagent is applied, the test strip is pressed against the metal and the reagent is transferred from the metal to the test strip.

The transfer printing method comprises transferring the reagents from a die to the test strip in the desired pattern. The die is made with the appropriate pattern on its surface and then coated with the desired, specially prepared reagent. A rubber stamp mechanism is pressed against the die to transfer the reagent in the desired pattern from the die to the rubber stamp. The rubber stamp is then pressed against the test strip to transfer the reagent, in the same pattern, to the test strip.

Each of the above-mentioned reagent printing techniques has significant disadvantages. The most common disadvantage is the requirement that the reagents must be specially prepared. Additionally, if a variety of reagents are to be printed onto a single test strip, the strip must be carefully aligned prior to each printing. This alignment procedure increases the cost and decreases the throughput of the printing process. Moreover, a special die or screen must be produced for each pattern to be printed. A further disadvantage arises in that the above printing methods are unable to place reproduceable minute quantities of reagent on the test strip.

It is an object of the present invention to provide a printing and dispensing method and apparatus which avoids these disadvantages.

SUMMARY OF THE PRESENT INVENTION

The present invention is directed to a reagent dispensing and printing apparatus and method, wherein the apparatus comprises a transducer operative to eject a substantially uniform quantity of reagent in a precise predetermined direction.

According to one preferred embodiment of the present invention used in dispensing reagent fluids, a jetting tube is concentrically located with a piezoelectric transducer. The jetting tube comprises an orifice at one end and a reagent receiving aperture at the other end. The receiving end of the jetting tube is connected to a filter which is in turn connected to a reservoir containing a selected reagent. A jetting control unit supplies an electrical pulse of short duration to the transducer in response to a command issued by a computer. The electrical pulse causes the volume defined by the jetting tube to expand by an amount sufficient to intake a small quantity of reagent fluid from the reservoir. At the end of the pulse duration, the transducer de-expands propelling a small quantity of the reagent fluid through the orifice and into a fluid recepticle. If desired, additional droplets may be deposited in the recepticle or the recepticle aligned with an additional jetting tube for receiving an additional reagent fluid.

An additional preferred embodiment of the present invention may be used for printing reagent fluids onto a print medium. In this embodiment, the jetting tube is aligned with the printing medium such that the propelled droplet impacts a precise position on the medium. The jetting tube or print medium may then be repositioned and another droplet expelled from the jetting tube. The process may be repeated until a desired configuration of the reagent fluid is printed on the medium.

One advantage of the present invention is that precise minute quantities of reagent fluid may be dispensed or printed in a reproducible manner. Additionally, the method and apparatus may be used to emit droplets of fluids having a wide range of reagent fluid viscosities and surface tensions. The reagents do not in general have to be specially adapted for use with the present invention.

The invention itself, together with further objects and attendant advantages, will best be understood by reference to the following detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic representation of a first preferred embodiment of the present invention showing the use of multiple jetting heads to meter and dispense reagent fluid.

FIGURE 2a is a perspective view of a first preferred embodiment of the jetting head of the present invention.

FIGURE 2b is a cut-away perspective view of the preferred embodiment of Fig. 2a taken along lines 2b-2b with the contact pins removed.

FIGURE 2c is a sectional representation of the preferred embodiment of Fig. 2a taken along lines 2c-2c.

FIGURE 2d is a sectional representation of the preferred embodiment of Fig. 2c taken along lines 2d-2d.

FIGURE 2e is a sectional representation of the jetting tube and transducer of the preferred embodiment of Fig. 2b taken along lines 2e-2e.

FIGURE 3 is a schematic representation of a second preferred embodiment operating in the drop on demand mode as a reagent printing system.

FIGURE 4 is a schematic representation of a third preferred embodiment operating in the continuous mode as a reagent printing system.

FIGURE 5a is a schematic representation of a portion of the jetting head control unit showing the LED strobe circuit.

FIGURE 5b is a schematic representation of a portion of the jetting head control unit showing the high voltage power supply circuit.

FIGURE 5c is a schematic representation of a portion of the jetting head control unit showing the print control circuit.

FIGURE 5d is a schematic representation of a portion of the jetting head control unit showing a portion of the print pulse generator.

FIGURE 5e is a schematic representation of a portion of the jetting head control unit showing an additional portion of the pulse generator.

FIGURE 6a is a perspective view of a second preferred embodiment of the jetting head of the present invention.

FIGURE 6b is an exploded view of the preferred embodiment of Fig. 6a.

FIGURE 7 is a sectional representation of a third preferred embodiment of the jetting head of the present invention.

FIGURE 8 is a sectional view of a symmetrical portion of a fourth preferred embodiment of the jetting head of the present invention.

FIGURE 9 is a graph of the drop mass of the emitted droplets as a function of emission frequency for several fluid viscosities.

FIGURE 10 is a graph of the velocity of the emitted droplets as a function of frequency for several fluid viscosities.

FIGURE 11 is a graph of the total weight of fluid emitted as a function of the number of emitted droplets for a given fluid.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Turning now to the drawings, Fig. 1 shows a schematic representation of a first preferred embodiment of a reagent dispensing system generally represented as reference numeral 30. The dispensing system 30 comprises a plurality of reagent fluid reservoirs 200, a plurality of filters 300, a plurality of reagent jetting heads 400, a plurality of jetting head control units 500, an interface unit 600, a computer 700, transportation unit 902, a plurality of fluid mixing cells 904 and a detection station 906.

The reservoir 200 holds a selected quantity of reagent fluid for dispensing. The reservoir 200 is maintained at atmospheric pressure by suitable means such as an atmospheric vent. The reagent fluid is transferred from the reservoir 200 through the filter 300 to the reagent jetting head 400. The filter 300 is placed between the reservoir 200 and the jetting head 400 to ensure that any particular foreign matter in the reagent fluid is trapped before entering the jetting head 400.

The plurality of jetting heads 400 and the detection station 906 define a processing path. Each jetting head 400, which is described in detail below, ejects uniformly sized droplets 2 of reagent fluid. The droplets 2 are propelled, with controlled velocity and direction, towards a selecting mixing cell 904 positioned along

the processing path by the transportation unit 902. The mixing cells 904 are comprised of non-reactive material and function as minute holding tanks for the dispensed reagent fluid.

The plurality of jetting heads 400, shown in Fig. 1, are positioned sequentially along the processing path. Alternately, some or all of the plurality of jetting heads 400 may be positioned with respect to the transportation unit 902 such that the heads 400 direct the droplets 2 into a selected mixing cell 902 simultaneously.

The jetting heads 400 and the transportation unit 902 are controlled by the computer 700. The computer 700 issues commands to an interface unit 600 which is electrically connected to the transportation unit 902 and to the jetting head control unit 500. The interface unit 600 is of conventional design and is used to control the transfer of information between the computer 700 and the jetting control unit 500. The interface unit 600 is also used to control the transfer of information between the computer 700 and the transportation unit 902.

A first embodiment of the reagent jetting head is shown in Figs. 2a - 2e and generally represented by numeral 400. The jetting head 400 comprises a two piece symmetrical housing 402, 404. The housing 402, 404, when assembled, is adapted to form an orifice aperture 406, an air vent and reagent supply channel 410 and a transducer chamber 403, shown in Fig. 4b. Four screws 408, adapted to respective housing screw apertures 416, hold the housing 402, 404 in an assembled configuration.

The jetting head 400 further comprises a jetting tube 432, a piezo-electric transducer 434 and a reagent fluid supply tube 430. The jetting tube 432 defines a tapered orifice 433 at one end and a fluid receiving aperture 431 at the other end for expelling and receiving fluid, respectively. The piezo-electric transducer 434 is cylindrically shaped and secured concentrically about the mid-region of the jetting tube 432 with epoxy or other suitable means.

The piezo-electric transducer 434, shown in Fig. 2e, defines a first and second end and comprises a section of cylindrically shaped piezeo-electric material 435. An inner nickel electrode 437 covers the inner surface of the cylinder 435. The electrode 437 wraps around the first end of the cylinder 435 a sufficient distance to enable electrical connection external to the cylinder 435.

A second nickel electrode 436 covers the majority of the outer surface of the cylinder 435. The second electrode is electrically isolated from the first electrode 437 by an air gap at the face of the second end of the cylinder 435 and by an air gap on the outer surface of the cylinder 435 near the first end. When an electrical pulse is applied to the first and second electrodes 437, 436 a voltage potential is developed radially across the transducer material 435. The voltage potential causes the radial dimensions of the transducer 435 to change, which causes the volume defined by the transducer 434 to also change.

The jetting tube 432 is positioned in the transducer chamber 403 such that the receiving end 431 extends beyond the rearward end of the transducer 434. The receiving end 431 of the jetting tube 432 is inserted into one end of a reagent supply tube 430. The supply tube 430 is sealingly held to the jetting tube 432 by concentric teeth 412 formed by the housing sections 402, 404. The teeth 412 not only seal the supply tube 430 to the jetting tube 432, but, also, seal the supply tube 430 to the housing 402, 404.

The second end of the supply type 430 passes through the channel 410 and into a reagent reservoir 200. The reservoir 200 contains the reagent fluid to be dispensed by the jetting head 400. As the reagent fluid is dispensed, air is supplied to the reservoir 200 through the channel 410 to prevent the creation of a vacuum in the reservoir 200. The reservoir 200 is releasably attached to the housing 402, 404 and held in place by frictional forces. A reservoir cap 202 is flexibly attached to the reservoir 200 and adapted such that the cap 202 may be used to secure the opening in the reservoir 200 when the reservoir 200 is disengaged from the housing 402, 404.

The position of the jetting tube 432 defines the horizontal plane of the jetting head 400. The jetting tube 432 and the transducer 434 are held in a pre-defined vertical relationship with respect to the housing 402, 404 by means of two upper vertical alignment pins 418 and two lower vertical alignment pins 418. The two upper vertical alignment pins 418 extend horizontally from the housing section 402 into the transducer chamber 403. Similarly, the two lower vertical alignment pins 418 extend horizontally from the housing section 404 into the transducer chamber 403. Each vertical alignment pin 418 is formed integrally with the respective housing sections 402, 404.

The jetting tube 432 and the transducer 434 are held in a predefined horizontal relationship with respect to the housing 402, 404 by means of four horizontal alignment pins 424. Two of the horizontal alignment pins 424 extend horizontally from the housing section 402 approximately midway into the transducer chamber 403. Similarly, two of the horizontal alignment pins 424 extend horizontally from the housing section 404 approximately midway into the transducing chamber 403. Each horizontal alignment pin 424 is formed integrally with the respective housing section 402, 404. The alignment pins 418, 424, sealing teeth 412 and orifice aperture 406 are aligned and adapted to hold the jetting tube 432 and transducer 434 such

that the orifice 433 of the jetting tube 432 extends into the orifice aperture 406.

An electrical transducer activation pulse is supplied to the piezo-electric transducer 434 from the jetting head control unit 500 by means of two contact pins 422. A quantity of fluid will be dispensed from the jetting tube for each applied activation pulse. The activation pulse can be produced by a variety of conventional circuits or commercially available units. Therefore a detailed description of such a circuit will not be provided. However, a circuit for producing a series of activation pulses is provided in the description of the printing embodiment below. Due to the dif fering constraints involved in dispensing and printing, the circuit in the printing embodiment is not required to produce only a single pulse. However, one skilled in the art could, if desired, modify the circuit to produce a single pulse on demand for use in the dispensing embodiment.

Each contact pin 422 defines an enlarged head 423 which is adapted to contact the respective first and second electrodes 437, 436 located on the outer surface of the transducer 434. Two contact pin holders 414, integral with the housing 402, 404, are positioned to hold the respective contact pins 422 under the pin heads 423 such that each pin head 423 electrically engages the appropriate electrode 437, 436 of the transducer 434. Two contact pin engaging posts 420 extend from the housing 402, 404 opposite the contact pin holders 414 to engage and hold the contact pins 422 against the contact pin holders 414. The ends of the contact pins 422 opposite the pin heads 423 extend through the housing 402, 404 by means of contact pin apertures 421. Since the housing sections 402, 404 are formed symmetrically to one another, the contact pins 422 may be optionally attached above the transducer 434.

In operation, the reservoir 200 containing reagent fluid is fastened to the jetting head 400 such that the fluid supply tube 430 extends into the reagent fluid. The filter 300 may be fitted to the free end of the supply tube 430 or positioned inside the reservoir 200. Air is supplied through the channel 410 around the supply tube 430 to prevent the reservoir 200 from falling below atmospheric pressure. The air is prevented from entering around the supply tube 430 and into the transducer chamber 403 by the seal created between the sealing teeth 412 and the supply tube 430. The jetting tube 432 may be primed by slightly pressurizing the reservoir 200 to cause the reagent fluid to travel through the supply tube 430 and into the jetting tube 432. Once primed, the fluid is prevented from substantially withdrawing from the jetting tube 432 by the surface tension of the reagent fluid at the orifice 433.

The transducer activation pulse is conducted to the contact pins 422 of the jetting head 400. The contact pins 422 communicate the high voltage pulse to the electrodes 437, 436 of the transducer 434 with polarity such that the concentrically mounted transducer 434 expands. The rate of expansion is controlled by the rise time of the high voltage pulse which is preset to generate a rapid expansion. The expansion of the transducer 434 causes the jetting tube 432, which is epoxied to the transducer 434, to also expand. The expansion of the tube 432 generates an acoustic expansion wave interior to the tube 432 which travels axially towards the orifice 433 and towards the fluid receiving aperture 431. When the expansion wave reaches the orifice 433, the reagent fluid is partially drawn inwardly. However, the surface tension of the fluid acts to inhibit substantial inward fluid movement.

When the expansion wave reaches the end 431 of the tube 432, the expansion wave is reflected and becomes a compression wave which travels towards the center of the piezo-electric tube 434. The high voltage pulse width is adapted such that when the reflected compression wave is beneath the piezo-electric tube 434, the high voltage pulse falls, resulting in a de-expansion of the transducer 434 and the jetting tube 432. This action adds to the existing acoustic compression wave in the interior of the jetting tube 432. The enhanced compression wave travels toward the ori fice causing reagent fluid to be dispensed from the tube 432. The fluid is propelled from the orifice 433 as a small droplet 2 and deposited in the selected mixing cell 904 positioned by the transportation unit 902. One droplet 2 is dispensed for each transducer activation pulse. This mode of dispensing is referred to as the drop on demand mode.

In some instances, the droplet 2 may be accompanied by at least one smaller satelite droplet. However, even if satelite droplets are present, the volume and velocity of the reagent droplets 2 are highly reproduceable. This reproduceability allows for precise dispensing of uniform, controllably sized droplets 2 of reagent fluid into the mixing cell 904.

The droplets 2 of reagents impact the mixing cell 904 with sufficient force and volume to cause fluidic mixing of the reagents. Once the desired amounts of the selected reagents are deposited in the selected mixing cell 904, mixing cell 904 is transported to the detection station 906 where the mixed reagents may be extracted for use or analyzed for assay results.

The dispensing system 30 provides numerous advantages based upon the ability of the reagent jetting head 400 to rapidly and reproduceably eject uniform quantities of a wide range of reagents. The reaction times of some chemical processes are dependent upon the volume of the reagents used. The ability of the dispensing system 30 to dispense such minute amounts of reagents thereby reduces the processing time

of certain chemical assays. Furthermore, some chemical assays require a wide range of dilution ratios. Many conventional dispensing systems are unable to dispense the reagents in volume small enough to make the desired assay practical. The dispensing system of the pres ent invention overcomes this disadvantage.

In addition to dispensing reagent fluids, certain embodiments may be used for precision printing of reagents onto a printing medium such as filter paper to produce an assay test strip. A printing system 10 using the present invention is represented in Fig. 3. Structure similar in form and function to structure described above will be designated by like reference numerals. The printing system 10 comprises a reagent fluid reservoir 200, a filter 300, a reagent jetting head 400, a jetting head control unit 500, an interface 600, a computer 700, and an x-y plotter 800.

The x-y plotter 800 is a commercially available pen plotter, mechanically modified in a conventional manner such that the pen is replaced with the jetting head 400. The general operation and structure of the plotter 800 will not be described in detail. The plotter 800 accepts commands from the computer 700 thru a standard RS-232 serial interface contained within the interface unit 600. The plotter 800 processes the commands and produces control signals to drive an x-axis motor (not shown) and a y-axis motor (not shown). The x-axis motor is used to position the jetting head 400 and the y-axis motor is used to position a drum (not shown) to which the printing target 1 is attached.

The plotter 800 produces a pen down signal PENDN. This signal is applied to the control unit 500 and indicates that the plotter 800 is ready to begin a printing operation.

The control unit 500 also receives control signals from the interface unit 600. These signals include signals HIGHER*, LOWER* to control the magnitude of the pulse applied to the transducer 434; a reset signal RST to reset the control unit 500; and a series of print signals PRT*. The generation of these signals will not be described in detail since their production is performed by the conventional interface unit 600.

The jetting head 400 and fluid supply system 200, 300 are initialized and operate substantially as described above. The jetting head control unit 500, shown in Figs. 5a - 5e comprises a print control circuit 510, a pulse generator 530, a high voltage supply 540, and a strobe pulse generator 560. The control unit 500 also comprises a power supply. However, since the power supply is of conventional design it will not be shown or described in detail.

The print control circuit 510 receives the pen down signal PENDN from the plotter 800 and comprises a transistor Q100, a one-shot circuit U100, two NAND-gates U101, U102, a line decoder multiplexer U107 and four inverters U103-U106. The pen down signal PENDN is applied to the base of the transistor Q100 by resistors R100, R101 and diode D100. The emitter of transistor Q100 is tied to ground and the collector is connected to the +5 volt supply by resistor R102.

The one-shot U100 comprises inputs A, B and an output Q. The B input of the one-shot U100 is connected to the collector of the transistor Q100 and the A input is tied to ground. The time period of the pulse produced by the one-shot U100 is determined by a resistor R104, a variable resistor R105 and a capacitor C100. The output Q of the one-shot U100 is combined with the collector output of the transistor Q100 by the NAND-gate U101 and then inverted by the NAND-gate U102. The circuit is operative to produce an adjustable delay in the application of the pen down signal PENDN to the control unit 500.

The line decoder U107 is circuited to function as a 3 input AND-gate. The output of the NAND-gate U102 is applied to the first input of the decoder U107; the print signal line PRT* comprising a series of pulses from the interface unit 600 is applied to the second input; and a jetting head ON/OFF signal from switch S1 is applied to the third input. The inverter U106 inverts the output of the line decoder U107 to generate the print control signal PRT* and the inverters U103-U105 invert the control signals LOWER*, HIGHER*, and RST signals, respectively.

The high voltage supply 540, shown in Fig. 5b, provides +175 volts DC to produce a maximum pulse of +150 volts peak to peak at the reagent jetting head 400. The high voltage supply 540 comprises differential amplifier U12 and transistors Q1, Q2, Q13, Q14. A stable reference voltage of -2.5 volts DC is produced at the junction of a reservoir R13, connected to the -15 volt supply, and a diode CR6, connected to ground. The reference voltage is combined with a resistor R14 to produce an adjustable, stable voltage reference for the amplifer U12. The reference voltage is applied to the inverting input of the amplifier U12 through a resistor R11. The noninverting input of the amplifier U12 is connected to ground by a resistor R12. The amplifier U12, in combination with a feedback resistor R10, produces an output signal proportional to the difference of the voltage reference signal and the ground potential.

The output of the amplifier U12 is applied to the base of the transistor Q2 whose collector is connected to the +15 volt supply. The signal produced at the emitter of the transistor Q2 is applied to the base of the transistor Q1 through resistors R8, R6, R5, a transformer L1 and diodes CR4, CR2, CR1. The emitter of the transistor Q1 is connected to ground and the collector is connected to the +15 voltage supply through the

transformer L1. A diode CR3 connects the collector of the transistor Q1 to the junction of the resistor R5 and the diode CR4. The transistor Q1 is biased for proper operation by resistors R7, R6, R5. The resistor R7 and a capacitor C22 connect the junction of the resistor R8, R6 to the +15 voltage supply.

The transistor Q1 and the transformer L1 form a "flyback" blocking oscillator. Any increase in current supplied by the transistor Q1 produces an increase in energy transferred through the secondary winding of the transformer L1 and diode CR5. Therefore, an increase in current supplied by the transistor Q1 results in an increase in power available to the high voltage output. The diodes CR1-CR4 form a "Baker clamp" which prevents transistor Q1 from saturating. The clamp thereby avoids transistor storage time.

The diode CR5 is connected to a multiple pi filter formed by the inductors L3, L2, capacitors C24, C21, C41 and resistors R29. The multiple pi filter attenuates ripple and switching spikes in the signal supplied to the transistor Q13 which produces the high voltage output V++. A resistor R64 connects the base of the transistor Q13 to the emitter and to the resistor U29. The base is also connected to the collector of the transistor Q14 by a resistor R65. The base of the transistor Q14 is connected to the +15 volt supply by a resistor R67 and to ground by a resistor R66. The emitter of the transistor Q13 provides a signal HV SENSE which is fed back to the inverting input of the amplifier U12 through a resistor R9. The high voltage output V++ is produced at the collector of the transistor Q13. The proper biasing of the transistor Q13 is provided by resistor R64 and the biasing circuit comprising the transistor Q14, resistors R67, R66, R65.

The pulse generator 530, shown in Figs. 5d, 5e, comprises an opto-isolator U18, a one-shot U23, a digital to analog (D/A) converter U30 and two binary counters U24, U25. The pulse generator 530 accepts control signals PRT*, LOWER*, HIGHER*, RST and produces the activation pulse which is applied to the transducer 434. In normal operation, the PRT* control signal is supplied to the opto-isolator U18 by a jumper JMP between contact points E5, E6. The opto-isolator U18 is of conventional design and comprises a light emitting diode (LED) circuit and a photo-element circuit. A resistor R15 operates as the load resistor for the LED circuit of the isolator and a capacitor C25 suppresses transient noise on the voltage supply to the isolator U18. The output of the isolator U18 is applied to one input of the one-shot U23 whose time constant is adjustably determined by resistors R38, R25 and a capacitor C30. The pulse from the non-inverting output of the one-shot U23 is fed to the base of a transistor Q9. A resistor R39 sets the approximate base current of the transistor Q9 which is used as a level shifter for converting the CMOS signal level to the +15 volt DC signal level.

The control of the rise and fall rates of the pulse generator 530 is accomplished by directing a pair of current source transistors Q11, Q12 to charge and discharge a capacitor C57. The transistor Q11 is operative as a source of current and the transistor Q12 is operative as a sink for current. A transistor Q10 controls the level of the current by applying an appropriate bias current through a resistor R56 to the base of the transistor Q11. The biasing of the transistors Q11, Q12 is critical to the proper rise and fall rates. Therefore precision voltage references CR13, CR15 are used to provide respective bias reference voltages. A temperature compensation network is formed from zener diodes CR14, CR16 and resistors R55, R54 to maintain stable operation of the transistors Q11, Q12, respectively. The variable resistors R49, R52 may be used to adjust the fall time and rise time, respectively, of the output pulse applied to the reagent jetting head 400. A plurality of resistors R45, R46, R47, R48, R49, R51, R52, R53, R56, R57, R58 are used to properly bias the transistor Q10, Q11, Q12 and capacitors C55, C60 are circuited to maintain stability of the circuit.

The impedance of the output stage of the rise and fall circuitry Q10, Q11, Q12 is very high. With such a high impedance, circuit elements attached to the capacitor C57 could affect the linearity of the rise and fall time constants. Therefore, an FET input operational amplifier U32 is used as an impedance interface. The amplifier U32 is configured in the noninverting mode and circuited with capacitors C58, C59 for stability.

The output of the amplifier U32 is applied to an inverting amplifier U31 by means of a resistor R62. The amplifier U31 inverts and conditions the pulse control signal with the aid of resistors R59, R60. Resistors R61, R63, connected to the -15 voltage supply, provide a means for adjusting the DC level offset of the amplifier U31 output signal. Capacitors C51, C52 are connected to enhance the performance and stability of the circuit.

The output of the amplifier U31 is applied by means of a resistor R41 to the positive voltage reference signal input REF(+) of the D/A converter U30. The negative voltage reference signal input REF(-) is tied to ground by a resistor R40. The D/A converter U30 produces output signals IOUT, IOUT* which are proportional to the difference between the positive and negative voltage reference signal inputs REF(+), REF(-). Capacitors C48, C49, C50 are connected to the D/A converter U30 to enhance stability.

The D/A converter outputs IOUT, IOUT* are also proportional to an 8-bit binary value applied to inputs B1-B8. The binary value is supplied by the counters U24, U25 which are controlled by the function signals LOWER*, HIGHER* and RST. The LOWER* signal and the HIGHER* signals are applied to the count up and

count down inputs CU, CD of the counter U24 by means of opto-isolators U19, U20. The carry and borrow outputs CY, BR of the counter U24 are connected with the count up and count down inputs CU, CD of the counter U25. The reset inputs RST of both counters U24, U25 receive the RST signal by means of an opto-isolator U21. Resistors R16, R17, R18 are used as load resistors for the LED circuits of the isolators U19, U20, U21 and capacitors C26, C27, C28 are used to enhance the stability of the isolator circuits.

The counters U24, U25 may optionally be preloaded to the selected 8-bit binary value through input lines TP0-TP7. The input lines TP0-TP7 are normally biased to the logical high signal state by resistive network U22. The selected binary value is loaded into the counters U24, U25 by pulling the respective inputs TP0-TP7 low and applying an external, active low, load signal EXT LOAD to pin TP8. The load signal pin TP8 is connected to the load inputs LOAD of the counters U24, U25 and conditioned by a clipping circuit comprised of diodes CR9, CR10 and a pull-up resistor of the resistor network U22.

The noninverted and the inverted outputs IOUT, IOUT* are connected to the inverting and noninverting inputs of a differential amplifier U29. The output of the amplifier U29 is fed back to the invert ing input by a resistor R50. The amplifier U29 converts the current output of the D/A converter U30 to a voltage output. Capacitors C56, C47 are provided to enhance circuit stability.

The output of the amplifier U29 is applied to the noninverting input of the amplifier U28. The output of the amplifier U28 is fed back to the inverting input by means of a capacitor C46 and a resistor R37. The inverting input is also connected to ground by a resistor R36. To enhance the frequency response of the amplifier U28, a resistor R43 and a capacitor C54 are connected between the frequency compensation input FC and ground. An adjustable DC offset is provided by connecting the output offset inputs OF, OF with a variable resistor R42. The wiper of the resistor R42 is connected to the high voltage power supply output V++.

The output of the amplifier U28 is also connected to the base of a transistor Q4 and through diodes CR11, CR12 to the base of a transistor Q7. The transistor Q4, Q7, Q3 and resistors R30-R35 form an output circuit capable of driving high capacitive loads at high slew rates and wide bandwidth. The variable resistor R31 may be used to set the maximum current through the bias network R30, R33 by measuring the voltage drop across resistor R35.

The strobe generator 560 produces a strobe pulse and comprises transistors Q101-Q105 and a one-shot circuit U108. The strobe intensity is determined by the circuit comprising the transistors Q101-Q104 and resistors R109-R115. The circuit is connected to the anode of the LED 900 and receives two inputs from the interface unit 600 to produce four levels of light intensity in the LED 900.

The activation aand duration of activation of the LED 900 is determined by the one-shot U108 and the transistor Q105. The one-shot U108 comprises inputs A, B and an output Q. The strobe signal STROBE is applied to the B input from the interface unit 600. The duration of the one-shot U108 output pulse is controlled by the adjustable RC network R107, R108. The output Q is applied to the base of the transistor Q105 by resistor R108. The collector of the transistor Q105 is connected to the cathode of the LED 900 to draw current through the LED 900.

The computer 700, control unit 500 and plotter 800 must be initialized. The initialization of the computer 700 and the plotter 800 will not be discussed since these units are of conventional design and operation.

To initialize the jetting head control unit 500, the computer 700 directs the interface unit 600 to issue a reset command. The reset signal RST is conducted to the control unit 500 whereupon the counters U24, U25 are cleared. The computer 700 then retrieves from its memory, or by conventional operator input, the desired digital setting for the D/A converter. This setting may also be calculated from data and may be tailored to specific sizes of jetting heads 400 or reagent fluids. The computer 700 then issues a series of commands, through the interface unit 600, to increment or decrement the counters U24, U25 to correspond to the desired binary setting. If the command directs that the counters are to be raised, then the HIGHER* signal is applied through the opto-isolator U20 to the count up CU input of the counter U24. Similarly, if the command directs that the counters are to be lowered then the LOWER* signal is applied through the opto-isolator U19 to the count down CD input of the counter U24. Since the carry and borrow outputs CY, BR of the counter U24 are connected to the count up and count down inputs CU, CD, respectively, of the counter U25, the digital setting applied to the D/A converter U30 may range from 0 to 255. Alternately, the counters U24, U25 could be initialized to a desired setting by loading the binary value on the lines TP0-TP7 and strobing the EXT LOAD line.

Once the control unit 500 and the plotter 800 are initialized, the printing cycle may begin. The computer 700 issues a command to the interface unit 600 to produce the series of PRT* signal pulses. The computer 700 then commands the plotter 800 to print, for example, a line along a selected path. The plotter 800 positions the jetting head 400 and target 1 and issues the pen down signal PENDN. The signal is delayed by the print control circuit 510 to ensure that the target 1 is properly positioned. At the expiration of the

delay, the signal is ANDed with the closed-enable switch S1 and the series of print pulses PRT'. The result of the AND operation is the application of the PRT' pulses to the pulse generator circuit 530.

The PRT' signal is applied through the jumper JMP to the opto-isolator U18 and then to the one-shot U23. The one-shot U23 produces a pulse signal which is then converted from CMOS signal levels to the 15 volt DC signal level by the transistor Q9. The rise and fall circuitry comprising Q10, Q11, Q12 converts the square wave pulse into a pulse having the rise and fall characteristics preset by the resistors R49, R52. The conditioned pulse is then amplified by the amplifier U32 and applied to the amplifier U31.

The amplifier U31 converts the polarity of the conditioned pulse to that acceptable by the D/A converter U30 and supplies an adjustable DC offset. The DC offset is used to counteract possible distortion attributable to the amplifier U31. The distortion arises in that, for the amplifier U31 to be adequately responsive, a small degree of current must flow through the resistor R41. This current creates an offset condition at the output of the amplifier U29 which is then scaled by the D/A converter U30 in correspondence with the binary data. The resistor R63 allows a small amount of current to be applied to the amplifier U31 to control the offset voltage attributable to the current flowing through the resistor R41.

The D/A converter U30 scales the difference between the inputs REF(+), REF(-) using the binary data supplied to input lines B1-B8 to produce a current output pulse IOUT and a current inverted output pulse IOUT'. The two outputs IOUT, IOUT' are fed to the amplifier U29 which convert the current outputs into a single voltage output. The scaled, conditioned pulse is then applied to the output circuit comprising the amplifier U28 and the transistors Q3, Q4, Q5, Q6, Q7. The circuit produces a high voltage pulse with the aforementioned rise and fall characteristics to drive the piezo-electric transducer 434.

The high voltage pulse is applied to the transducer 434 and causes a droplet 2 of fluid to be propelled onto the target 1. Since the pen down signal PENDN is still applied, additional droplets 2 are produced from the jetting head 400. The plotter 800 moves the jetting head 400 and target 1 along the desired path during the emission of the droplets 2 to produce the desired printed line. When the printing is complete, the plotter 800 removes the pen down signal PENDN and the droplet emission stops. Of course it should be understood that dots, circles and the like could be produced by appropriate positioning of the target 1 and jetting head 400.

The size and uniformity of the droplets 2, as well as the presence of any satelite droplets, may be observed with the aid of the scope 950 and the LED 900. The scope 950 and the LED 900 are positioned such that the droplets 2 pass between the scope 950 and the LED 900 and within the focal range of the scope 950. The strobe pulse when applied to the LED 900 causes the LED 900 to momentarily flash. The timing of the activation and the width of the pulse may be adjusted such that the flash occurs when the fluid, expelled in response to the high voltage pulse, is between the scope 950 and the LED 900. The dispensed quantity of fluid may then be observed in flight or at or near the momement of separation from the orifice 433. Corrections based on the observation may then be made to the system 10.

Since each droplet 2 is small in volume, the droplet 2 may be rapidly absorbed by the target 1, thereby allowing rapid and precise placement of a variety of reagents on the target 1 with reduced drying time and reduced potential of fluidity mixing. In addition, the ability to place small droplets 2 in a precise manner enables the target 1 to be printed in a high density matrix with a variety of reagents as isolated matrix elements.

In some printing applications, particularly when printing fluids of flow viscosity and surface tension, it may be desirable to force the fluid through the jetting tube 432 under pressure and allow the vibrations produced by the transducer 434 to break the emitted fluid stream into precise droplets 2. Under this mode of printing, the emission of droplets 2 can not be stopped by cessation of the tranducers activation pulse. It is therefore necessary to prevent fluid emission by other means. One preferred means of momentarily stopping emission of the droplets is shown schem atically in Fig. 4. In this arrangement, structure similar to structure represented in Fig. 3 in form and function, is represented by like reference numerals.

The arrangement, generally represented by the numeral 20, includes a closed reagent recirculation system comprising a normally close three way valve 970, a sump 960 and a recirculation pump 980. In the continuous mode, the reagent fluid is forced out the orifice 433 by hydraulic pressure and broken into a series of substantially uniform droplets 2 by movement of the transducer 434. A regulated, filtered air supply 100 is used to pressurize the reagent fluid reservoir 200. The reagent fluid within the reservoir 200 may optionally be agitated by a magnetic stirer unit 990. This is especially useful for reagent fluids comprising suspended particles.

The three-way valve 970 comprises a common channel, a normally open channel and a normally closed channel. The fluid is forced through the filter 300 and applied to the normally closed channel of the valve 970. When the normally closed channel is closed, the normally open channel of the valve 970 functions as a vent for the reagent jetting head 400. The common channel is connected to the reagent supply tube 430

of the jetting head 400. The reagent supply tube 430' is also connected to the sump 960.

In operation, the normally closed channel is opened by an appropriate signal supplied by the computer 700 which also closes the normally open channel. When the normally closed channel is opened, fluid is permitted to pass to the sump 960 and to the jetting head 400. The sump 960 collects the reagent fluid not transferred to the jetting head 400. The sump 960 supplies the collected fluid to the inlet side of the recirculating pump 980 which returns the fluid to the reservoir 200. The returned fluid is then mixed with the contents of the reservoir 200 and is available for recirculation.

When operating in the continuous mode, rather than interrupt the continuous stream of print pulses to the jetting head 400, the printing may be momentarily stopped by closing the normally closed channel of the valve 970. The closing of the normally closed channel stops the flow of reagent fluid to the jetting head 400 and allows the jetting head 400 to vent to atmospheric pressure. With the fluid supply blocked, the transducer 434 is unable to expel further droplets 2. Thus, if positioning of the target 1 by the plotter 800 requires a longer time interval than the time between droplet 2 emission, the computer 700 may close the normally closed channel of the valve 970. The plotter 800 may then position the target 1 or position a new target 1 as desired.

When printing, the active ingredient of the reagent is tailored to achieve a desired concentration per unit area on the target 1. However, to a certain extent the final concentration per unit area can be adjusted by varying the density of the droplets 2 printed on the target 1. The preferred embodiment is particularly well suited to this application due to its ability to print precise, discrete pels of reagent.

A second preferred embodiment of the jetting head is illustrated in Figs. 6a-6b and is generally represented as 400'. The jetting head 400' comprises housing formed into three sections 401', 402', 403'. The housing section 403' comprises a recessed region which forms the reagent fluid reservoir 200' when the housing section 403' is positioned against housing section 402'.

The jetting head 400' further comprises a piezo-electric transducer 434' and a reagent jetting tube 432' similar to those of the first embodiment. The jetting head 400' and the transducer 434' are most clearly shown in Fig. 6b. The jetting tube 432' defines an orifice 433' at one end and a reagent fluid receiving aperture 431' at the other end. The transducer 434' is mounted to the jetting tube 432' concentrically about the mid-region of the tube 432' with epoxy.

The transducer 434' and the jetting tube 432' are positioned in channels 420', 418', 416' located in the housing sections 402', 401'. The channel 416' comprises a plurality of sealing teeth 412' operative to engage and seal against the fluid receiving end 431' of the jetting tube 432'. The channel 416' is connected to the reagent fluid supply channel 430'. The supply channel 430' is connected with the fluid reservoir 200' by means of an aperture 431' through the housing section 402', shown in Fig. 6b.

The reservoir 200' comprises a flexible reservoir lining 201' adapted to contain the reagent fluid. The lining 201' comprises one aperture which is connected to the housing 402' to allow the fluid to pass from the lining 201'. A vent (not shown), located in the housing 403', allows the space between the reservoir 200' and the lining 201' to be vented or pressurized. A filter 300' is positioned within the aperture 202' to trap unwanted particulate foreign matter.

Electrical pulses are supplied to the transducer 434' by means of two contact pins 422'. The pins 422' are inserted through respective apertures 419' of the housing section 402' and respective apertures 421' of the housing section 403'. Two thin electrically conductive strips 410', 411', shown in Fig. 6b, are used to connect the transducer 434' with the contact pins 422'. A protective shield 405' extends from the housing position 403' to partially isolate the protruding portions of the contact pins 422'.

The function and operation of the jetting head 400' is similar to that of the jetting head 400 and therefore will not be discussed in detail. The collapsible inner lining 201' of the reservoir 200 allows the jetting tube 432' to be primed by pressurizing the reservoir 200' through the vent 205'. Once primed, the jetting head 400' may be used as described above in reference to the jetting head 400.

The jetting head 400' provides an advantage in that the entire fluidic system is contained in one housing. Such containment allows for fast and efficient replacement of the jetting heads without fluid contamination problems.

A third preferred embodiment of the jetting head is shown in Fig. 7 and generally represented as 400". The jetting head 400" comprises a housing 403", a reagent fluid supply tube 406", a piezo-electric transducer 434" and an orifice plate 404". The housing 403" defines a conically shaped fluid chamber 432". An orifice plate 404", defining an orifice 433", is fastened to the housing 403" such that the orifice 433" is located at or near the apex of the conical fluid chamber 432".

The fluid feed tube 406" is attached to the housing 403" and defines a supply channel 430". The supply channel 430" is in fluid communication with the fluid chamber 432" by means of a connecting channel 431". The base of the fluid chamber 432" is formed by the disc-shaped transducer 434". The transducer 434" is

held in position by a hold down plate 402" attached to the housing 403". The electrical connec tions to the transducer 434" are of conventional design and are therefore not shown. The housing 403" further comprises a threaded aperture 406" for mounting the jetting head 400".

The jetting head 400" operates in a manner similar to the jetting heads described above. However, in this jetting head the transducer 434" is normally disk shaped. When the electrical pulse is applied, the transducer 434" bends slightly, thereby altering the volume of the conically shaped jetting chamber 432". The change in volume of the chamber 432" causes the expulsion of fluid through the orifice 433" and the intake of fluid through the supply channel 430" as described in reference to the jetting head 400.

A fourth preferred embodiment of the jetting head is shown in Fig. 8 and is generally represented as 400‴ . The jetting head 400‴ is very similar in form and function to the jetting head 400 and will not be described in detail. The jetting head 400‴ comprises two symmetrical housing sections. The sections may be connected together by means of apertures 409‴ and screws, not shown. When assembled, the housing sections 404‴, 402‴ form a T-shaped supply channel 410‴ .

In operation, the jetting head 400‴ functions in a manner similar to the jetting head 400. The jetting head 400‴ is especially suited for use in the continuous mode, but may also be used in the drop on demand mode. In the continuous mode, the fluid is circulated continuously through the supply channel 430‴ allowing the jetting tube 432‴ to withdraw as much fluid as required.

By way of illustrating and with no limitations intended the following information is given to further illustrate the above described embodiments. The computer 700 is an IBM Corporation Personal Computer with 640 kbytes of RAM memory. The interface unit 600 is a Burr Brown interface unit model number PC 20001. The plotter 800 is manufactured by Houston Instrument as model number DMP-40. Communication between the plotter 800 and the interface unit 600 is performed through a standard asynchronous serial communication port.

The electrical pulse applied to the jetting head 400 to activate the transducer 434 comprises a rise time of approximately 5 usecs, a fall time of approximately 5 usecs and a pulse width of approximately 35 usecs. When the transducer 434 is operated in the drop on demand mode, the voltage potential of the pulse is 60 volts plus or minus 10 volts and the pulse frequency can be up to 4 khz. When the transducer 434 is operated in the continuous mode, the voltage potential of the pulse is 30 volts plus or minus 10 volts and the pulse frequency can be up to 10 khz.

The jetting tube 432 is manufactured from a pyrex glass tube and measures .027 inches outside diameter and .020 inches inside diameter. The tube is drawn to a closed taper in an electric furnace. The tapered end is then cut and ground to a desired orifice opening of .002 to .004 inches in diameter. The tube is cut to a final length of .945 inches in the case of the dispenser embodiment and ultrasonically cleaned in acetone. After being cleaned and dried the large end of the tube is fire polished. If desired, the orifice end of the tube may receive a coating, such as a hydrophobic polymer, to enhance droplet separation from the tube.

The supply tube 430 is formed from .023 inch inside diameter and .38 inch outside diameter polyethylene tubing produced by Intramedic Corp. as model number #14 170 11B. During assembly, one end of the tubing is stretched over a warm tapered mandrel. The stretched end of the supply tube 430 is then inserted over the large fire polished end of the jetting tube 432. The assembly is then cleaned and baked in a circulating air oven at 50°C. for 10 minutes.

The transducer 434 was purchased from Vernitron of Cleveland, Ohio as model number PZT-5H. The electrodes 437, 436 are comprised of nickel and are separated from each other on the outer surface of the transducer by approximately .030 inches. The jetting tube 432 is inserted into the cylindrical piezo-electric tube 434 and secured with epoxy manufactured by Epoxy Technology of Bellenca, Massachusetts as model number 301. The epoxy is applied at the junction of the tube 432 and transducer 434 with a syringe. The epoxy flows along the tube 432 inside the transducer 434 by capillary action. The assembly is then baked in a circulating air oven at 65°C. for one hour to cure the epoxy.

The contact pins 422 are secured to one of the housing sections 402, 404 with a drop of epoxy. The transducer jetting tube 434, 432 is placed in the housing such that the orifice end 433 of the tube 432 protrudes approximately .030 inches from the housing 403, 404. A drop of silver epoxy is placed between each contact pin 422 and the transducer 434 to ensure a secure electrical connection. Epoxy is also applied to the junction of the housing 402, 404 and supply tube 430. The other section of the housing 402, 404 is then screwed into place.

The periphery of the housing 402, 404 is sealed with a capillary sealer such as cyclohexanone. Epoxy is then added around each contact pin 422 and around the orifice end 433. The assembly is then baked in a circulating air oven at 65°C. for one hour.

The filter 300 is formed from a polyester mesh with 30 um pores and positioned in a polypropylene

housing. The air pressure supplied to the reservoir 200 during continuous printing operations is regulated at approximately 10 to 30 psi.

The reagents used have the following characteristics:

Printing (drop on demand mode):
Fluid viscosity range: 1 - 30 centipoises
Fluid surface tension: 20 - 70 dyne/cm

Printing (continuous mode):
Fluid viscosity range: up to 50 centipoises
Fluid surface tension: not measured

Dispensing (drop on demand mode):
Fluid viscosity range: 2 - 30 centipoises
Fluid surface tension: 20 - 70 dyne/cm

A measure of the performance and selected operating characteristics for a typical jetting head are presented in Figs. 9-11. Fig. 9 is a graph of the mass of a droplet as a function of droplet emission frequency for three fluids. The viscosity of the fluids were 1, 5 and 24 centipoise and the transducer excitation pulse width was 35 microseconds. As shown in Fig. 9, the higher fluid viscosity results in a more stable operating performance of the jetting head. Fig. 10 is a graph of droplet velocity as a function of droplet emission frequency for fluid viscosities of 1, 5 and 24 centipoise. The log of the total fluid weight as a function of the log of the number of droplets emitted is shown in Fig. 11. The fluid used has a viscosity of 2 centipoise, a surface tension of 20 dynes/cm, and a density of .8 grams/cc. The transducer excitation pulse was 80 volts and the excitation frequency was approximately 711 Hz.

Some blood typing reagents and some allergen reagents have very low viscosities and surface tensions. Although in some cases viscosity modifiers, such as glycerol, dextran, glucose, and the like, may be added to increase the viscosity, a few reagents are adversely affected by such modifiers.

Developing stable and reproduceable demand mode jetting is difficult with very low viscosities. Although droplet emission can be established at some fundamental frequencies, the droplets dispensed may have small satelite droplets which reduce the accuracy for metering and dispensing applications. However, even with the satelite drops, sufficient reagent is adequately delivered for most print applications without a substantial decrease in print quality.

Glycerin may be used as a viscosity modifier to improve jetting reliability and to prevent obstruction of the orifice arising from evaporation of the reagent fluid components. Glycerin has been found especially beneficial for those reagents containing particulate material. The evaporation of the fluid component results in a concentration of glycerin located at the orifice. The plug of glycerin substantially prevents further evaporation of the reagent fluid. During the next activation cycle of the transducer, the plug of glycerin is expelled from the orifice.

When operating in the dispensing mode the volume of the droplets can be varied to substantially uniformly contain from 100 pico-liters to 1 micro-liter. The droplets can be produced at a rate of approximately 1 khz to 8 khz. When operating in the printing mode the size of the pel made by each droplet measures approximately .001-.012 inches in diameter.

A copy of the program used in the computer 700 for a printing operation is attached hereto as Appendix A. The values, manufacturer and manufacturing part number of the circuit components of the jetting control unit 500 are substantially as follows:

Ref. Numeral of Component	Description and Value	Manufacturer and Part No.
R39,45-48,57, 58	RES.10KOHM½WATT5%C.F.	
R66	RES.150OHM½WATT5%C.F.	
R3	RES.15KOHM½WATT5%C.F.	
R34	RES.16KOHM½WATT5%C.F.	
R50	RES.2.4KOHM½WATT1%M.F.	DALE RL079242G
R13,23,36,40, 41	RES.2.4KOHM½WATT5%C.F.	
R56	RES.20KOHM½WATT5%C.F.	
R8	RES.220OHM½WATT5%C.F.	
R6	RES.27OHM1WATT5%C.C.	
R7,12,25	RES.2KOHM½WATT5%C.F.	
R67	RES3.6KOHM½WATT5%C.F.	
R51,53	RES.3.9KOHM½WATT5%C.F.	
R29	RES.300KOHM½WATT5%C.F.	
R61	RES.30KOHM½WATT1%M.F.	DALE RL079303G
R15-18,26-28, 54,55,64	RES.4.7KOHM½WATT5%C.F.	
R62	RES.45.3KOHM½WATT1%M.F.	DALE RN55D4532F
R30,33	RES.47OHM½WATT5%C.F.	
R21	RES.470OHM½WATT5%C.F.	
R19	RES.47KOHM½WATT5%C.F.	
R35	RES.510OHM½WATT5%C.F.	
R43	RES.6.2KOHM½WATT5%C.F.	
R60	RES.7.5KOHM½WATT5%C.F.	
R37	RES.75KOHM½WATT5%C.F.	
R9	RES.76KOHM½WATT1%M.F.	DALE RN60D7682F
R11	RES.820OHM½WATT5%C.F.	
U2,11,14,16,22	RES.DIP NETWRK.47KOHM	CTS 761-1R47K
C21,41,45	CAP.AXIAL1MF@250VDC	MALLORY #TC56
C24	CAP.AXIAL220MF@250VDC	MALLORY LP2219250C7P3
C10	CAP.AXIAL ALUM ELEC. 4700 OMF@25VDC	MALLORY TCG472U025N1C
C1,2,3,55,60	CAP.RADIAL DIPPED TANT. 10MF@25VDC	KEMET T350E106M025AS
C53	CAP.RADIAL DIPPED TANT. 1MF@35VDC	KEMET T350A105K035AS
C36	CAP.RADIAL DIPPED TANT. 47MF@10VDC	KEMET T350H566MC10AS

Ref. Numeral of Component	Description and Value	Manufacturer and Part No.
C54	CAP.RADIAL SILV MICA 100PF300VDC	KAHGAN SD5101J301
C57	CAP.RADIAL SILV MICA 20PF300VDC	KAHGAN SP12200J301
C49	CAP. RADIAL SILV. MICA 39PF300VDC	KAHGAN SP12390J301
C39	CAP.RADIAL X7R MLC .015MF@50VDC	KEMET C315C102K1R5CA
C6	CAP.RADIAL X7R MLC .022MF@50VDC	KEMET C315C223K5R5CA
C30,35,37	CAP.RADIAL Z5U MLC .015MF@50VDC	KEMET C315C153K5R5CA
C4,7	CAP.RADIAL Z5U MLC .01MF@50VDC	KEMET C315C103K5R5CA
C4,5,6,9,11-19, 22,23,25-28 C31-34,37,42,43 47,48,50-52 C56,58,59	CAP.RADIAL Z5U MLC .22MF@50VDC	KEMET C322C224M5U5CA
C46	CAP.VARI.2-12PF.	JOHANSEN #9626
CR7,8,9,10, 11,12,17	DIODE SIL.	ITT.FAIRCHLD.1N4148
CR1,2,3,4	DIODE SIL.FAST	GENL.INST.EGP10D
CR5	DIODE SIL.FASTHIVOLT	GENL.INST.UF4007
CR6,13,15	DIODE SIL.REF.2,500VDC	NATL.SEMI-LM3852-2.5
CR14,16	DIODE SIL.ZENER3.8V.25WATT	MOTOROLA 1N4622A
U6,13,15,17	SWITCH 8 POSITION DIP	CTS 206-8
Q2,9,12	TRANSTOR.COMMON NPN	MOTOROLA 2N2222A
Q8,10,11	TRANSTOR.COMMON PNP	MOTOROLA 2N2907A
Q4	TRANSTOR.HIVOLTHIFREQ.NPN	MOTOROLA MPSU10
Q7	TRANSTOR.HIVOLTHIFREQ.PNP	MOTOROLA MPSU60
Q1	TRANSTOR.HIVOLTHIINPN	TI,MOTOROLATIP48
Q3,14	TRANSTOR.HIVOLTNPN2N3439	MOTOROLA 2N3439
Q13	TRANSTOR.HIVOLTPNP	MOTOROLA MJE5731
U5,27	IC 1-SHOT 74HC221	NATL.SEMI MM74HC221N
U23,26	IC 1-SHOT 74LS221	NATL.SEMI DM74LS221N
U7-10	IC COMPARATOR 74HC688	NATL.SEMI MM74HC688N
U30	IC CONVERTER DAC0800	NATL.SEMI DAC0800LCN
U24,25	IC COUNTER 74HC193	NATL.SEMI MM74HC193N
U28	IC HI SLEW HI VOLT OP AMP	BURR-BROWN 3584JM
U1	IC HYBRID DC/DC CONVERTER	BURR-BROWN MODEL 724
U4	IC OC DRIVER SN7406	NATL.SEMI DM7406N
U3	IC OCTAL LATCH 74HC374	NATL. MM74HC374N
U12,29,31,32	IC OP AMP LF256	NATL.SEMI LF256H
U18,19,20,21	IC OPTO ISOLATOR	HEWLTT-PCKRD HCPL2300
R24,42,63	POT100KOHM½WATT10%	BOURNS 3622-1-104
R38,49,52	POT10KOHM½WATT10%	BOURNS 3622W-1-103
R20	POT25KOHM½WATT10%	BOURNS 3622W-1-253
R14,31	POT2KOHM½WATT10%	BOURNS 3622W-1-202

Ref. Numeral of Component	Description and Value	Manufacturer and Part No.
VRI	REGULATOR 5VDC	NATL.LM340T-5.0
R10	RES.1MEGOHM¼WATT5%C.F.	
R2,4	RES.1.2KOHM¼WATT5%C.F.	
R32	RES.1.6KOHM¼WATT5%C.F.	
R44	RES.1.8KOHM¼WATT5%C.F.	
R1	RES.10MEGOHM¼WATT5%C.F.	
R5,R22	RES.100HM¼WATT5%C.F.	
R65	RES.100KOHM¼WATT5%C.F.	
R59	RES.10KOHM¼WATT1%M.F.	DALE RN55D1002F
R100	RES.2700HM	
R101,108	RES.4700HM	
R102,103 106,109,110	RES.1KOHM	
R104	RES.47000HM	
R105	POT.100KOHM	
R107	POT.10KOHM	
R111,113	RES.2200HM	
R112	RES.220HM	
R114,115	RES. 470HM	
C100	CAP.10MF035 VPC	
C108	CAP.10000 PF	
D100	DIODE	1N4148
Q100,105	TRANSTOR	2N2222
Q101,102	TRANSTOR	2N3906
Q103,104	TRANSTOR	2N3904
U100,U108	IC I-SHOT	74LS123
U103,104 105,106	IC INVERTOR	74LS04
U108	IC LINE DECODER	74LS138

Of course, it should be understood that a wide range of changes and modifications can be made to the preferred embodiments described above. For example, the transducer could be of a type other than piezo-electric such as magneto-strictive, electro-strictive, and electro-mechanical. It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, which are intended to define the scope of this invention.

APPENDIX

```
Reagent Jet Printer                                                                                         PAGE  1
Reagent Calibration                                                                                         07-14-86
                                                                                                            12:26:57
Offset  Data    Source Line                                                IBM Personal Computer BASIC Compiler V2.00

0030    0006    REM $TITLE:'Reagent Jet Printer' $SUBTITLE:'Reagent Calibration' $LINESIZE: 132
0030    0006    'MODULE   - "REACAL"
0030    0006    '
0030    0006    'AUTHOR   - N. A. Enevold
0030    0006    '
0030    0006    'COPYRIGHT (C) 1985 ABBOTT LABORATORIES
0030    0006    'REVISION - 2.0 07-01-86 NAE MicroFab modifications
0030    0006    '           - 1.0 02-11-86 NAE Creation of initial code
0030    0006    '
0030    0006    'SYSTEM   - This code can only be compiled by the BASCOM
0030    0006    '              COMPILER, it will not run under the INTERPRETER!!
0030    0006    '
0030    0006    'DESCRIPTION:
0030    0006    '         The reagent calibrate module presents a menu with 12 items arranged
0030    0006    '         in 3 columns of 4 rows.  The arrow keys allow movement around the
0030    0006    '         table, the + and - keys increment or decrement values in the first
0030    0006    '         column, and the enter key executes commands in the third column.
0030    0006    '         The second column is an array of ASCII strings representing reagent name,
0030    0006    '         concentration, density, and viscosity.  The values entered in column one
0030    0006    '         are drop frequency, pulse width, strobe delay, and nozzle number.
0030    0006    '         The commands in the third column are start/stop, load, save, and exit.
0030    0006    '
0030    0006    'DATA DICTIONARY
0030    0006    '         MENU%          Pointer to which menu item is active (0-11)
0030    0006    '         MENU$(17,1)    Array for strings used to display the menu
0030    0006    '         MENU(17,4)     Array for numbers in the menu display
0030    0006    '         DIFF%          Differential to move MENU% at arrow key input
0030    0006    '         TYPE%          Pointer set during menu scan to direct action
0030    0006    '         KEYBUF$        Storage for string input from menu display
0030    0006    '         A$             Destination for single keystroke inputs
0030    0006    '         FILE$          String where filename is built for reagent data file
0030    0006    '         REANAME$       String where reagent name is stored
0030    0006    '         R%             Row to display special graphics character in menu
0030    0006    '         C%             Column to display special graphics character in menu
0030    0006    '         M%             Special graphics character is read into here
0030    0006    '         OLD.AMP.VALUE% Integer value for setting pulse amplitude
0030    0006    '         DIG.VAL%       Value set to digital port 0 to inc/dec amplitude
0030    0006    '
0030    0006    SUB REAGENT.CALIBRATE STATIC
0047    0006
0047    0006          DIM MENU$(17,1),MENU(17,4)
0048    01FE
0048.   01FE          GOSUB INITIALIZE:         'read init. values and set screen
004E    01FE
004E    01FE          WHILE TYPE% <> 1
0059    0200
0059    0200            TYPE% = 0
0060    0200            A$ = ""
006A    0204
006A    0204            WHILE A$ = ""
0079    0204              A$ = INKEY$
0083    0204              IF ACTIVE% = 1 AND DOWNTIME < TIMER THEN GOSUB PEN.DOWN
00AD    0204            WEND
00B0    020A
```

```
Reagent Jet Printer                                                                    PAGE  2
Reagent Calibration                                                                   07-14-86
                                                                                      12:26:57
Offset  Data    Source Line                             IBM Personal Computer BASIC Compiler V2.00

 00B0   020A          IF A$ = CHR$(13) THEN TYPE% = 1:                  'execute <cr>
 00CA   020A          IF A$ = "+" THEN TYPE% = 2:                       'increment variable
 00E0   020A          IF A$ = "-" THEN TYPE% = 3:                       'decrement variable
 00F6   020A          IF A$ = CHR$(0) + CHR$(72) THEN TYPE% = 4:        'up arrow key
 011B   020A          IF A$ = CHR$(0) + CHR$(80) THEN TYPE% = 5:        'down arrow key
 0140   020A          IF A$ = CHR$(0) + CHR$(75) THEN TYPE% = 6:        'left arrow key
 0165   020A          IF A$ = CHR$(0) + CHR$(77) THEN TYPE% = 7:        'right arrow key
 018A   020A          IF A$ > CHR$(47) AND A$ < CHR$(123) THEN TYPE% = 8:' ascii 0 - z
 01C2   020A
 01C2   020A          ON TYPE% GOSUB T1, T2, T3, T4, T5, T6, T7, T8
 01DB   020A
 01DB   020A        WEND
 01DF   020A        TYPE% = 0
 01E6   020A
 01E6   020A        EXIT SUB
 01EA   020A   REM $PAGE
```

```
Reagent Jet Printer                                                          PAGE  3
Reagent Calibration                                                          07-14-86
                                                                             12:21:37
Offset  Data    Source Line                  IBM Personal Computer BASIC Compiler V2.00

 01EA   0208    '*********** SUBROUTINES FOR THIS MODULE ***********
 01EA   0208
 01EA   0208    T1:             '(cr) execute command
 01EF   0208            IF MENU% < 12 THEN TYPE% = 0:RETURN:    'exit to print menu, no action
 0205   020C            ON MENU% - 11 GOSUB T1A, T1B, T1C, T1D
 0214   020C            IF MENU% < 15 THEN TYPE% = 0
 022C   020C            RETURN.
 0238   020C
 0230   020C    T1A:            'start/stop drop flow
 0235   020C            IF MENU$(12,0) = "START" THEN GOSUB START.INK
 025A   020C            IF MENU$(12,0) = "STOP " THEN GOSUB STOP.INK
 027F   020C            MENU$(12,0) = TEMP$
 029A   0210            COLOR 0,7:GOSUB DISPMENU
 02AC   0210            RETURN
 02B0   0210
 02B0   0210    START.INK:
 02B5   0210            TEMP$ = "STOP "
 02BF   0210            CALL DOT.ON:            'in module PCI
 02C3   0210            LOCATE 17,71:COLOR 27,0:PRINT "PRINTING";
 02F1   0210            ACTIVE% = 1
 02F8   0210            RETURN
 02FC   0210
 02FC   0210    STOP.INK:
 0301   0210            TEMP$ = "START"
 0308   0210            CALL DOT.OFF:           'in module PCI
 0317   0210            LOCATE 17,71:COLOR 15,0:PRINT "        ";
 033D   0210            ACTIVE% = 0
 0344   0210            RETURN
 0348   0210
 0349   0210    T1B:            'load reagent profile
 034D   0210            IF MENU$(6,1) = "" THEN LOCATE 25,1:PRINT "Reagent Name is not specified";:GOSUB ANYKEY:RETURN
 0391   0210
 0391   0210            GOSUB SEARCH
 0397   0210
 0397   0210            IF I% < (REANUM% + 1) THEN GOTO FOUND
 03A3   0214            LOCATE 25,10-LEN(MENU$(6,1))/2:PRINT MENU$(6,1);" not Found";
 0401   0214            GOSUB ANYKEY:   'wait for a keyhit
 040A   0214            RETURN
 040E   0214
 040E   0214    FOUND:
 0413   0214            FILE$ = RIGHT$(STR$(I%),LEN(STR$(I%))-1) + "REA.RJP"
 0437   0218            OPEN FILE$ FOR INPUT AS #1:     'set pattern data file for read
 0448   0218            INPUT #1,MENU(0,0):     'read frequency
 0468   0218            INPUT #1,MENU(1,0):     'read amplitude
 048B   0218            INPUT #1,MENU(2,0):     'read strobe delay
 04AE   0218            INPUT #1,MENU(3,0):     'read pulse width
 04D1   0218            INPUT #1,MENU(4,0):     'read rise time
 04F4   0218            INPUT #1,MENU(5,0):     'read fall time
 0519   0218
 0519   0218            INPUT #1,MENU$(7,1):    'read concentration
 053D   0218            INPUT #1,MENU$(8,1):    'read density
 0561   0218            INPUT #1,MENU$(9,1):    'read viscosity
 0585   0218            INPUT #1,MENU$(10,1):   'read surface tension
 05A9   0218
```

```
Offset  Data   Source Line

 05A9   0218          CLOSE #1:        'done with data file
 05B0   0218
 05B0   0218          OPEN "READEF.RJP" FOR OUTPUT AS #1
 05C2   0218          PRINT #1,FILE$:                 'save filename in default file
 05D2   0218          PRINT #1,MENU$(6,1):    'save the directory name as well
 05F4   0218          CLOSE #1
 05FB   0218          GOSUB DISP.PARMS:        'show all parameters
 0601   0218          RETURN
 0605   0218
 0605   0218   T1C:          'save reagent profile
 060A   0218          IF MENU$(6,1) = "" THEN LOCATE 25,1:PRINT "Reagent Name is not specified";:GOSUB ANYKEY:RETURN
 064E   0218          OPEN "READIR.RJP" FOR INPUT AS #1
 065F   0218          INPUT #1,REANUM%
 0671   0218          CLOSE #1
 0678   0218          IF REANUM% < 80 THEN GOTO SAVE.REA
 0687   0218          LOCATE 25,1:PRINT "Directory is Full (80 reagents max.)"
 06A1   0218          GOSUB ANYKEY:RETURN
 06AB   0218   SAVE.REA:
 06B0   0218          GOSUB SEARCH
 06B6   0218          IF I% > REANUM% THEN GOTO SAVEREA1
 06C7   0218          REANUM% = I%
 06CE   0218          COLOR 15,0
 06DA   0218          LOCATE 25,1:PRINT MENU$(6,1);" already exists. Replace it with new values? ";
 070C   0218          A$ = ""
 0716   0218          WHILE A$ = ""
 0725   0218                  A$ = INKEY$
 072F   0218          WEND
 0732   0218          LOCATE 25,1:PRINT SPACE$(79);
 074F   0218          IF A$ = "Y" OR A$ = "y" THEN GOTO REPLACE
 0778   0218          RETURN
 077C   0218
 077C   0218   SAVEREA1:
 07B1   0218          KILL "READIR.OLD":       'delete old backup directory
 07B8   0218          NAME "READIR.RJP" AS "READIR.OLD":       'save old directory
 0792   0218          OPEN "READIR.OLD" FOR INPUT AS #1
 07A3   0218          OPEN "READIR.RJP" FOR OUTPUT AS #2:     'set up new dir
 07B5   0218
 07B5   0218          INPUT #1,REANUM%:         'read number of dir entries
 07C7   0218          REANUM% = REANUM% + 1:  'increase by 1
 07D4   0218          WRITE #2,REANUM%:         'save in new directory
 07E1   0218
 07E1   0218          FOR I=1 TO REANUM% - 1
 07FA   021C              LINE INPUT #1,A$:   'read entry from old dir
 0807   021C              PRINT #2,A$:        'write entry in new directory
 0817   021C          NEXT I
 0832   0220
 0832   0220          CLOSE #1
 0839   0220
 0839   0220          PRINT #2,MENU$(6,1):    'write new entry to new directory
 0858   0220          CLOSE #2:        'done with directory
 0862   0220
 0862   0220   REPLACE:
 0867   0220          FILE$ = RIGHT$(STR$(REANUM%),LEN(STR$(REANUM%))-1) + "REA.RJP"
 088B   0220
```

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Reagent Jet Printer                                                                          PAGE  5
Reagent Calibration                                                                          07-14-86
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Offset  Data    Source Line                                       IBM Personal Computer BASIC Compiler V2.00

 0888   0220            OPEN FILE$ FOR OUTPUT AS #1:    'create new pattern data file
 0890   0220            WRITE #1,MENU(0,0):     'store frequency
 08B3   0220            WRITE #1,MENU(1,0):     'store amplitude
 08DC   0220            WRITE #1,MENU(2,0):     'store strobe delay
 08FB   0220            WRITE #1,MENU(3,0):     'store pulse width
 091E   0220            WRITE #1,MENU(4,0):     'store rise time
 093F   0220            WRITE #1,MENU(5,0):     'store fall time
 0962   0220
 0962   0220            WRITE #1,MENU$(7,1):    'store concentration
 0984   0220            WRITE #1,MENU$(8,1):    'store density
 09A6   0220            WRITE #1,MENU$(9,1):    'store viscosity
 09C8   0220            WRITE #1,MENU$(10,1):   'store surface tension
 09EA   0220
 09EA   0220            CLOSE #1:       'done with data file
 09F1   0220
 09F1   0220            OPEN "READEF.RJP" FOR OUTPUT AS #1
 0A03   0220            PRINT #1,FILE$:                 'save filename in default file
 0A13   0220            PRINT #1,MENU$(6,1):    'save the directory name as well
 0A35   0220            CLOSE #1
 0A3C   0220            RETURN
 0A40   0220
 0A40   0220    SEARCH:
 0A45   0220            OPEN "READIR.RJP" FOR INPUT AS #1
 0A56   0220            INPUT #1,REANUM%:       'read number of patterns in dir
 0A6B   0220            I% = 1:                         'set entry pointer
 0A6F   0220
 0A6F   0220    SLOOP:
 0A74   0220            LINE INPUT #1,A$:       'read next pattern name from dir
 0A81   0220            IF A$ = MENU$(6,1) THEN GOTO SEARCH.DONE:       'compare name with dir entry
 0AA5   0220            I% = I% + 1
 0AAE   0220            IF I% < (REANUM% + 1) THEN GOTO SLOOP:'check for done
 0AC1   0220    SEARCH.DONE:
 0AC6   0220            CLOSE #1
 0ACD   0220            RETURN
 0AD1   0220
 0AD1   0220    T10:            'return with no change to exit reagent calibrate
 0AD6   0220            PRINT #3,"UH";
 0AE6   0220            CLOSE #3:'      close com channel
 0AEB   0220            RETURN
 0AF1   0220
 0AF1   0220    T2:             'process "+" key
 0AF6   0220            IF MENU% > 5 THEN RETURN
 0B05   0220            NEWTIME = TIMER
 0B0F   0224            DELTATIME = NEWTIME - OLDTIME
 0B1F   022C            OLDTIME = NEWTIME
 0B29   022C            IF DELTATIME > 0.15 THEN MULT% = 1 ELSE MULT% = MULT% + 1
 0B48   022E            IF MULT% > 100 THEN MULT% = 100
 0B5B   022E            MENU(MENU%,0) = MENU(MENU%,0) + MENU(MENU%,3) * MULT%:  'add increment
 0B9F   022E            IF MENU(MENU%,0) > MENU(MENU%,1) THEN MENU(MENU%,0) = MENU(MENU%,1):    'check max value
 0C06   022E            COLOR 15,1:GOSUB DISPMENU:RETURN:                       'show new value
 0C1D   022E
 0C1D   022E    T3:             'process "-" key
 0C22   022E            IF MENU% > 5 THEN RETURN
 0C31   022E            NEWTIME = TIMER
```

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Reagent Jet Printer                                                                             PAGE  6
Reagent Calibration                                                                             07-14-86
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Offset  Data    Source Line                                       IBM Personal Computer BASIC Compiler V2.00

0C3B    022E            DELTATIME = NEWTIME - OLDTIME
0C4B    022E            OLDTIME = NEWTIME
0C55    022E            IF DELTATIME > 0.15 THEN MULT% = 1 ELSE MULT% = MULT% + 1
0C77    022E            IF MULT% > 100 THEN MULT% = 100
0C89    022E            MENU(MENU%,0) = MENU(MENU%,0) - MENU(MENU%,3) * MULT%:  'sub increment
0CCB    022E            IF MENU(MENU%,0) < MENU(MENU%,2) THEN MENU(MENU%,0) = MENU(MENU%,2):    'check min value
0D32    022E            COLOR 15,1:GOSUB DISPMENU:RETURN:                       'show new value
0D49    022E
0D49    022E    T4:             'process up arrow key
0D4E    022E            IF MENU% MOD 6 = 0 THEN RETURN:                 'in top row already
0D63    022E            DIFF% = -1:GOSUB NEWMENU:RETURN:        'move pointer up one
0D74    0230
0D74    0230    T5:             'process down arrow key
0D79    0230            IF MENU% MOD 6 = 5 THEN RETURN:                 'in bottom row already
0D8F    0230            DIFF% = 1:GOSUB NEWMENU:RETURN:                 'move pointer down one
0DA0    0230
0DA0    0230    T6:             'process left arrow key
0DA5    0230            IF INT(MENU% / 6) = 0 THEN RETURN       'in left column already
0DC5    0230            DIFF% = -6:GOSUB NEWMENU:RETURN:        'move pointer one left
0DD6    0230
0DD6    0230    T7:             'process right arrow key
0DDB    0230            IF INT(MENU% / 6) = 2 THEN RETURN       'in right column already
0DFE    0230            DIFF% = 6:GOSUB NEWMENU:RETURN:                 'move pointer one right
0E0F    0230
0E0F    0230    T8:             'input keys into KEYBUF$ until <cr> is entered
0E14    0230            IF MENU% > 10 THEN RETURN
0E23    0230            LOCATE 25,30:COLOR 31,0:PRINT "ENTER NEW VALUE";:COLOR 15,0
0E35    0230            KEYBUF$ = A$
0E5F    0234            WHILE A$ <> CHR$(13)
0E72    0234                    LOCATE 25,47:PRINT SPACE$(15);
0E8F    0234                    LOCATE 25,47:PRINT KEYBUF$;
0EA9    0234                    A$ = ""
0EB3    0234                    WHILE A$ = ""
0EC2    0234                            A$ = INKEY$
0ECC    0234                            IF ACTIVE% = 1 AND DOWNTIME < TIMER THEN GOSUB PEN.DOWN
0EF6    0234                    WEND
0EF9    0234                    IF A$ = CHR$(8) AND LEN(KEYBUF$) > 0 THEN KEYBUF$ = LEFT$(KEYBUF$,LEN(KEYBUF$)-1)
0F3B    0234                    IF A$ > CHR$(31) AND LEN(KEYBUF$) < 15 THEN KEYBUF$ = KEYBUF$ + A$
0F75    0234            WEND
0F79    0234
0F79    0234            IF MENU% > 5 THEN GOTO STORESTRING
0F88    0234
0F8B    0234            TEMP = VAL(KEYBUF$)     'temp has value of keys input
0F9B    0238
0F98    0238            'round off temp according to step size in menu array
0F98    0238            TEMP = INT(TEMP / (MENU(MENU%,3)) + .5) * MENU(MENU%,3)
0FD1    0238
0FD1    0238            'test TEMP for maximum and minimum values in menu array
0FD1    0238            IF TEMP > MENU(MENU%,1) THEN TEMP = MENU(MENU%,1)
1019    0238            IF TEMP < MENU(MENU%,2) THEN TEMP = MENU(MENU%,2)
104F    0238
104F    0238            'insert new value into menu array and update screen
104F    0238            MENU(MENU%,0) = TEMP
1063    0238            LOCATE 25,30:PRINT SPACE$(40);
```

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Reagent Jet Printer                                                    PAGE  7
Reagent Calibration                                                    07-14-86
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Offset  Data   Source Line                  IBM Personal Computer BASIC Compiler V2.00

 1098   0238           COLOR 0,7:GOSUB DISPMENU
 109A   0238           RETURN
 109E   0238
 109E   0238   STORESTRING:
 10A3   0238           MENU$(MENU%,1) = KEYBUF$
 10BF   0238           LOCATE 25,30:PRINT SPACE$(40);
 10DC   0238           COLOR 0,7:GOSUB DISPMENU
 10EE   0238           RETURN
 10F2   0238
 10F2   0238   PEN.DOWN:
 10F7   0238           DOWNTIME = TIMER + 1
 1107   0238           PRINT #3,"D";
 1117   0238           RETURN
 111B   0238
 111B   0238   ANYKEY:
 1120   0238           LOCATE 25,64:PRINT "Strike any key..";
 113A   0238           A$ = ""
 1144   0238           WHILE A$ = ""
 1153   0238                   A$ = INKEY$
 115D   0238           WEND
 1160   0238           LOCATE 25,1:COLOR 15,0:PRINT SPACE$(79);:COLOR 15,1
 1196   0238           RETURN
 119A   0238
 119A   0238   NEWMENU: 'write old item in yellow, point to and highlight new item
 119F   0238           COLOR 14,0:GOSUB DISPMENU
 11B1   0238           MENU% = MENU% + DIFF%
 11BD   0238           IF MENU% = 11 THEN MENU% = 10
 11CF   0238           IF MENU% > 15 THEN MENU% = 15
 11E1   0238           COLOR 0,7:GOSUB DISPMENU:RETURN
 11F7   0238
 11F7   0238   INITIALIZE:
 11FC   0238           'change to second screen and display messages
 11FC   0238           SCREEN 0,0,1,1:COLOR 7,0:CLS:LOCATE 10,28:PRINT "Initializing Menu Display";
 1240   0238           LOCATE 12,33:PRINT "Please Wait..."
 125A   0238
 125A   0238           'initialize variables
 125A   0238
 125A   0238           ACTIVE% = 0:'   not printing
 1261   0238
 1261   0238           'initialize plotter com channel
 1261   0238
 1261   0238           OPEN "COM1:2400,N,8,2" AS #3
 1273   0238           PRINT #3,";:UECS,EFV1,H";
 1283   0238
 1283   0238           'initialize digital port
 1283   0238           SCR% = 4
 128A   023A           CALL DIGITAL.OUT(SCR%)
 129A   023A           SCR% = 0
 12A1   023A           CALL DIGITAL.OUT(SCR%);          'pulse reset line to set amplitude to 0V.
 12B1   023A           SCR% = 4
 12B8   023A           CALL DIGITAL.OUT(SCR%)
 12C8   023A
 12C8   023A           'set hardware pulse width
 12C8   023A           CALL SET.DOT.WIDTH(5)   'in module PC1
```

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Reagent Jet Printer                                                                          PAGE  8
Reagent Calibration                                                                          07-14-86
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Offset- Data   Source Line                                  IBM Personal Computer BASIC Compiler V2.00

 120E   023C
 120E   023C          'initialize menu arrays
 120E   023C          RESTORE ARDATA
 1225   023C          FOR II=0 TO 17
 1223   023C                  READ MENU$(II,0),MENU$(II,1):
 1318   023C                  READ MENU(II,1),MENU(II,2),MENU(II,3),MENU(II,4)
 137C   023C          NEXT II
 138F   023C
 138F   023C          'set default reagent values
 138F   023C
 138F   023C          MENU(0,0) = 2000:              'frequency
 13A8   023C          MENU(1,0) = 0:                 'amplitude
 13C4   023C          MENU(2,0) = 1:                 'strobe delay
 13E0   023C          MENU(3,0) = 090:               'pulse width
 13FC   023C          MENU(4,0) = 470:               'rise time
 1418   023C          MENU(5,0) = 070:               'fall time
 1436   023C
 1436   023C          MENU(6,0) = 0:                 'name
 1452   023C          MENU(7,0) = 0:                 'concentration
 146E   023C          MENU(8,0) = 0:                 'density
 148A   023C          MENU(9,0) = 0:                 'viscosity
 14A6   023C          MENU(10,0) = 0:                        'surface tension
 14C2   023C
 14C2   023C          OLD.AMP.VALUE% = 0             'initial value of 0 volts
 14C9   023E
 14C9   023E          'change active displayed screen to first screen to draw and display parameters
 14C9   023E
 14C9   023E          SCREEN 0,0,0,1:CLS
 14E6   023E
 14E6   023E          COLOR 13:LOCATE 1,32:PRINT "REAGENT CALIBRATE";
 1507   023E          COLOR 9
 150E   023E          FOR I=2 TO 79
 1518   023E                  LOCATE 3,I:PRINT "D";:LOCATE 5,I:PRINT "D";:LOCATE 19,I:PRINT "D";
 156F   023E          NEXT I
 158A   023E          FOR I=4 TO 18
 1594   023E                  LOCATE I,1:PRINT "3";:LOCATE I,28:PRINT ":";:LOCATE I,69:PRINT ":";:LOCATE I,80:PRINT "3";
 1608   023E          NEXT I
 1626   023E          RESTORE TABLE
 1629   023E          FOR I=1 TO 12
 1637   023E                  READ RI,CI,NI:LOCATE RI,CI:PRINT CHR$(NI);
 166A   0244          NEXT I
 1685   0244
 1685   0244          'print three headings and instructions
 1685   0244          COLOR 10,0
 1691   0244          LOCATE 4,7:PRINT "DROP PARAMETERS";
 16A3   0244          LOCATE 4,39:PRINT "REAGENT PARAMETERS"
 16C5   0244          LOCATE 4,71:PRINT "COMMANDS";
 16DF   0244
 16DF   0244          COLOR 7:LOCATE 21,20:PRINT "Use ";:COLOR 15:PRINT CHR$(27);CHR$(32);CHR$(26);
 1729   0244          PRINT CHR$(32);CHR$(24);CHR$(32);CHR$(25);:COLOR 7:PRINT " to position highlighted cursor";
 1768   0244          LOCATE 22,18:PRINT "Use ";:COLOR 15:PRINT "+";:COLOR 7:PRINT " or ";:COLOR 15:PRINT "-";
 178E   0244          COLOR 7:PRINT" to scroll current value up or down";
 17D2   0244          LOCATE 23,26:PRINT "Use ";:COLOR 15:PRINT "DY";:COLOR 7:PRINT" to activate selection";
 1814   0244
```

```
Reagent Jet Printer                                                       PAGE   9
Reagent Calibration                                                        07-14-86
                                                                           12:26:57
Offset  Data    Source Line                       IBM Personal Computer BASIC Compiler V2.00

 1814   0244    DISP.PARMS:
 1819   0244            'display 18 menu choices in yellow
 1819   0244
 1819   0244            COLOR 14,0
 1825   0244            FOR MENU% = 0 TO 17
 1828   0244                    GOSUB DISPMENU
 1831   0244            NEXT MENU%
 1841   0244
 1841   0244            'set for reagent name and highlight it
 1841   0244            MENU% = 6:COLOR 0,7
 1854   0244            GOSUB DISPMENU
 185A   0244
 185A   0244            SCREEN 0,0,0,0
 186F   0244            RETURN
 1873   0244    REM $PAGE
```

```
Offset  Data    Source Line

1873    0244    DISPMENU:
1878    0244            LOCATE (MENU% MOD 6)*2+7,(INT(MENU%/6)*28+2)+15*INT(MENU%/12)
18D4    0244            PRINT MENU$(MENU%,0)
18F2    0244            IF MENU% > 5 THEN GOTO SHOWSTRING:'     no value to display
1901    0244            LOCATE (MENU% MOD 6)*2+7,MENU(MENU%,4)
1933    0244            PRINT USING MENU$(MENU%,1);MENU(MENU%,0);
1966    0244            IF MENU% > 2 THEN RETURN
1975    0244            ON MENU%+1 GOSUB SET.FREQ, SET.AMP, SET.DELAY
1986    0244            RETURN
198A    0244    SHOWSTRING:
198F    0244            IF MENU% > 10 THEN RETURN
199E    0244            LOCATE (MENU% MOD 6)*2+7,48
19BA    0244            PRINT "            "
19C7    0244            LOCATE (MENU% MOD 6)*2+7,48
19E3    0244            PRINT MENU$(MENU%,1)
1A02    0244            RETURN
1A06    0244
1A06    0244    SET.FREQ:
1A0B    0244            TEMP = MENU(0,0)
1A24    0244            CALL SET.DOT.RATE(TEMP):        'in module PCI
1A34    0244            LED% = 3-INT((TEMP+500)/1000)
1A57    0246            IF LED% < 0 THEN LED% = 0
1A69    0246            SCR% = 4 + (LED% * 32):                 'set LED intensity
1A89    0246            CALL DIGITAL.OUT(SCR%):                 'in module PCI
1A99    0246            RETURN
1A9D    0246
1A9D    0246    SET.AMP:
1AA2    0246            SCR% = CINT(MENU(MENU%,0) * 255 / 150):         'convert volts to binary number
1ACB    0246            IF SCR% = OLD.AMP.VALUE% THEN RETURN
1ADC    0246            TEMP% = SCR% - OLD.AMP.VALUE%:          'calculate delta
1AEB    0248            OLD.AMP.VALUE% = SCR%:                  'update old value to current value
1AEF    0248            DIG.VAL% = 6
1AF6    024A            IF TEMP% < 0 THEN DIG.VAL% = 5
1B08    024A            TEMP% = ABS(TEMP%)
1B15    024A            FOR I% = 1 TO TEMP%
1B22    024C                    SCR% = DIG.VAL% + (32*LED%)
1B3F    024C                    CALL DIGITAL.OUT(SCR%):                 'pulse higher or lower
1B4F    024C                    SCR% = 4 + (32 * LED%)
1B6F    024C                    CALL DIGITAL.OUT(SCR%):                 'set port to normal
1B7F    024C            NEXT I%
1B91    024C            RETURN
1B95    024C
1B95    024C    SET.DELAY:
1B9A    024C            TEMP = MENU(2,0)
1BB6    024C            CALL SET.STROBE.DELAY(TEMP):    'in module PCI
1BC6    024C            RETURN
1BCA    024C
1BCA    024C    REM $PAGE
```

```
 gent Jet Printer                                                                                          PAGE  11
 agent Calibration                                                                                     07-14-86
                                                                                                       12:26:57
 Offset  Data    Source Line                                          IBM Personal Computer BASIC Compiler V2.00

  1BCA   024C    '************ DATA USED BY THIS MODULE ***********
  1BCA   024C
  1BCA   024C    ARRDATA:
  1BCF   024C             DATA "Frequency            Hz","##,###",10000,1,1,16
  1BD1   024C             DATA "Amplitude            V ","###",150,0,1,19
  1BD3   024C             DATA "Strobe Delay         uS","##,###.#",15999.5,.5,.5,16
  1BD5   024C             DATA "Pulse Width            ","###",999,0,1,19
  1BD7   024C             DATA "Rise Time              ","###",999,0,1,19
  1BD9   024C             DATA "Fall Time              ","###",999,0,1,19
  1BDB   024C             DATA "Name","",0,0,0,0
  1BDD   024C             DATA "Concentration","",0,0,0,0
  1BDF   024C             DATA "Density","",0,0,0,0
  1BE1   024C             DATA "Viscosity","",0,0,0,0
  1BE3   024C             DATA "Surface Tension","",0,0,0,0
  1BE5   024C             DATA "","",0,0,0,0
  1BE7   024C             DATA "START","",0,0,0,0
  1BE9   024C             DATA "LOAD","",0,0,0,0
  1BEB   024C             DATA "SAVE","",0,0,0,0
  1BED   024C             DATA "EXIT","",0,0,0,0
  1BEF   024C             DATA "","",0,0,0,0
  1BF1   024C             DATA "","",0,0,0,0
  1BF3   024C
  1BF3   024C     TABLE:
  1BF8   024C             DATA 3,1,218
  1BFA   024C             DATA 3,28,210
  1BFC   024C             DATA 3,69,210
  1BFE   024C             DATA 3,80,191
  1C00   024C             DATA 5,1,198
  1C02   024C             DATA 5,28,206
  1C04   024C             DATA 5,69,206
  1C06   024C             DATA 5,80,181
  1C08   024C             DATA 19,1,192
  1C0A   024C             DATA 19,28,208
  1C0C   024C             DATA 19,69,208
  1C0E   024C             DATA 19,80,217
  1C10   024C
  1C10   024C     END SUB
  1C17   024C
  1C17   024C
  23EB-  024C

 50426 Bytes Available
 43960 Bytes Free

     0 Warning Error(s)
     0 Severe  Error(s)
```

```
Reagent Jet Printer                                                  PAGE   1
Pattern Entry/Modification                                          07-05-86
                                                                    10:46:13
Offset  Data    Source Line        IBM Personal Computer BASIC Compiler V2.00

 0030   0006    REM $TITLE:'Reagent Jet Printer' $SUBTITLE:'Pattern Entry/Modif
                ication'
 0030   0006    'MODULE    - "PATENT" Pattern creation, modification, and filing

 0030   0006    '
 0030   0006    'AUTHOR    - N. A. Enevold
 0030   0006    '
 0030   0006    'COPYRIGHT (C) 1985 ABBOTT LABORATORIES
 0030   0006    '
 0030   0006    'REVISION - 1.2 03-10-86 NAE Remove Mouse inputs
 0030   0006    '           1.1 02-20-86 NAE Add 80 pattern limit to save
 0030   0006    '           1.0 01-13-86 NAE Creation of initial code
 0030   0006    '
 0030   0006    'SYSTEM    - This code can only be compiled by the BASCOM
 0030   0006    '            COMPILER, it will not run under the INTERPRETER!!
 0030   0006    '
 0030   0006    'DESCRIPTION:
 0030   0006    '       This module allows the user to LOAD, SAVE, DIRectory, D
                RAW and
 0030   0006    '       enter repeat count and other parameters for a pattern t
                o be printed.
 0030   0006    '       The low-resolution graphics mode is selected and a menu
                 is displayed
 0030   0006    '       across the bottom of the screen.  Using arrow keys
 0030   0006    '       point to the action to be taken and then invoke that ac
                tion with the
 0030   0006    '       Enter key.  In the DRAW mode, another menu is
 0030   0006    '       displayed which allows the user to select from LINE, RE
                CTangle,
 0030   0006    '       Solid RECTangle, or CIRCLe pattern elements.
 0030   0006
 0030   0006    'DATA DICTIONARY
 0030   0006    '       SCNDAT%(50,5)     51 Row (Elements) by 6 Column array f
                or storing pattern elements
 0030   0006    '       CURSOR%(9)        Storage for cursor graphics icon
 0030   0006    '       MENU$(6)          Up to 7 menu names can be saved here
 0030   0006    '       ELNUM%            Count of number of elements in a patt
                ern
 0030   0006    '       X% Y%             Current location of graphics cursor
 0030   0006    '       GRID              Value of one dot space on the screen
                (default is 0.003")
 0030   0006    '       ROW% COL%         Location to print instructions
 0030   0006    '       A$                Storage for single key-strokes or inp
                ut strings
 0030   0006    '       MENUNUM           Which menu is being displayed (1 or 2
                )
 0030   0006    '       ITEM              Pointer to which menu item is highlig
                hted (0 - 6)
 0030   0006    '       REPEAT%           Number of times pattern is to be repe
                ated when printed
 0030   0006    '       XOFF  YOFF        X and Y axis distance between the pri
                nting of repeated patterns
 0030   0006    '       ROWSP COLSP       Row and Column spacing for printing m
                ultiple sets of patterns
```

```
Reagent Jel Printer                                                    PAGE   2
Pattern Entry/Modification                                             07-05-86
                                                                       10:46:13
Offset  Data    Source Line         IBM Personal Computer BASIC Compiler V2.00

 0030   0006    '       PATNUM%          -     Number of patterns stored in
                the pattern directory PATDIR.RJP
 0030   0006    '       DROW%  DCOL%       Row and Column location to display di
                rectory entrys
 0030   0006    '       NAME$              Pattern name to be LOADed or SAVEd to
                 directory
 0030   0006    '       I%  J%             Counters used to LOAD or SAVE the ele
                ment data from/to pattern data file
 0030   0006    '       FILE$              Name of pattern data file
 0030   0006    '       TEMP%              Which type of element is being drawn.
                  1 = Line    2 = Rectangle
 0030   0006    '
                 3 = Solid Rectangle  4 = Circle
 0030   0006    '       FLAG%              Same as TEMP% above
 0030   0006    '       STARTMSG$ ENDMSG$ Message display for startpoint and en
                dpoint of element entry
 0030   0006    '       X1% Y1%                   Starting cursor position for
                element being drawn
 0030   0006    '       DX% DY%                   Delta X and Y values used to
                re-position cursor after arrow key
 0030   0006    '       MAXITEM                   The highest number item in th
                e current menu display
 0030   0006    '       XS  XE             Starting and ending X position of the
                 menu highlighting blue box
 0030   0006    '       RADIUS%                   The calculated radius of a ci
                rcle to be displayed
 0030   0006    REM $PAGE
```

```
Reagent Jet Printer                                                        PAGE   3
Pattern Entry/Modification                                                 07-05-86
                                                                           10:46:13
Offset  Data    Source Line          IBM Personal Computer BASIC Compiler V2.00

 0030   0006    SUB PATENTRY STATIC
 0047   0006
 0047   0006            WIDTH 40:SCREEN 1:CLS
 005F   0006            DIM SCNDAT%(50,5),CURSOR%(9),MENU$(6)
 0060   029A            ELNUM% = 0:X%=0:Y%=0:GRID = 0.005
 007F   02A4
 007F   02A4            LINE (0,0)-(6,6),,B
 00A1   02A4            LINE (0,3)-(6,3),,B
 00C5   02A4            LINE (3,0)-(3,6),,B
 00E9   02A4            PRESET (3,3)
 00F5   02A4            GET (0,0)-(6,6),CURSOR%
 0116   02A4            CLS
 011D   02A4
 011D   02A4            LINE (0,0)-(319,190),,B
 0140   02A4
 0140   02A4            RESTORE INSTRUC
 0147   02A4            FOR I=1 TO 4
 0151   02A4                    READ ROW%,COL%,A$
 0164   02AC                    LOCATE ROW%,COL%:PRINT A$;
 0180   02AC            NEXT I
 019B   02B0
 019B   02B0    FIRST:
 01A0   02B0            MENUNUM = 1
 01AA   02B4            GOSUB SUBMENU
 01B0   02B4
 01B0   02B4            ON ITEM + 1 GOTO PATDIR, PATLOAD, PATSAVE, PATDRAW, REP
                EAT, PATEXIT
 01CD   02B8            GOTO FIRST
 01D0   02B8
 01D0   02B8    REPEAT:
 01D5   02B8            GOSUB ITEMBOXERASE:      'erase blue box around DIR
 01DB   02B8            LOCATE 25,1:PRINT SPACE$(39);    'erase menu line
 01FB   02B8            LOCATE 25,1:INPUT;"Enter Repeat Count  ",REPEAT%
 021B   02BA            LOCATE 25,1:PRINT SPACE$(39);    'erase menu line
 0235   02BA            LOCATE 25,1:INPUT;"Enter X Axis Offset ",XOFF
 0255   02BE            LOCATE 25,1:PRINT SPACE$(39);    'erase menu line
 0272   02BE            LOCATE 25,1:INPUT;"Enter Y Axis Offset ",YOFF
 0292   02C2            GOTO FIRST
 0296   02C2    PATEXIT:
 029B   02C2            WIDTH 80:SCREEN 0:CLS
 02B2   02C2            EXIT SUB
 02B6   02C2    REM $PAGE
```

```
Reagent Jet Printer                                                    PAGE  4
Pattern Entry/Modification                                             07-05-86
                                                                       10:46:13
Offset  Data    Source Line          IBM Personal Computer BASIC Compiler V2.00

 02B6   02C2    PATDIR:                      'list directory of patterns
 02BB   02C2            GOSUB ITEMEOIERASE:     'erase blue box around DIR
 02C1   02C2            LOCATE 25,1:PRINT SPACE$(39);   'erase menu line
 02DE   02C2            OPEN "PATDIR.RJP" FOR INPUT AS #1:       'open directory
         file
 02EF   02C2            INPUT #1, PATNUM%:      'read number of patterns in dir
        ectory
 0301   02C4            LINE (1,1)-(318,189),0,BF:      'erase graphics tablet
 0326   02C4            I = 0:                          'set counter
 0330   02C4
 0330   02C4    DISLOOP:
 0335   02C4            I = I + 1:              'set for next value
 0344   02C4            IF I > PATNUM% THEN GOTO DIREXIT:       'test for done
 035B   02C4            IF INT((I-1)/44) <> (I-1)/44 THEN GOTO SHOWNEXT
 0364   02C4            IF INT((I-1)/44) < 1 THEN GOTO SHOWNEXT
 03A9   02C4
 03A9   02C4            LOCATE 25,1:PRINT "More to Display. Continue ? (Y or N)
        ";
 03C3   02C4            GOSUB CORLOOP:  'wait for Y or N response
 03C9   02C4            IF A$ = "N" THEN GOTO DIREXIT:  'if N then don't contin
        ue
 03DC   02C4
 03DC   02C4            LINE (1,1)-(318,189),0,BF:      'erase graphics tablet
 0401   02C4
 0401   02C4    SHOWNEXT:
 0406   02C4            DROW% = ((I - 1) MOD 22) + 2:   'calculate row for disp
        lay
 0422   02C6            DCOL% = 4:                      'set column to 4
 0429   02C8            IF ((I - 1) MOD 44) > 21 THEN DCOL% = 23:'reset column
        if necessary
 044C   02C8
 044C   02C8            LINE INPUT #1, A$:      'read next name from directory
 0459   02C8            LOCATE DROW%,DCOL%:PRINT A$;    'PRINT NAME
 0475   02C8            GOTO DISLOOP
 0479   02C8
 0479   02C8    DIREXIT:
 047E   02C8            CLOSE #1:       'terminate access to PATDIR.RJP
 0485   02C8            GOTO FIRST
 0489   02C8
 0489   02C8    REM $PAGE
```

```
Reagent Jet Printer                                                  PAGE   5
Pattern Entry/Modification                                          07-05-86
                                                                    10:46:13
Offset  Data    Source Line         IBM Personal Computer BASIC Compiler V2.00

 0489   02C8    PATLOAD:
 048E   02C8            GOSUB ITEMGOIERASE:     'erase blue box around DIR
 0494   02C8            OPEN "PATDIR.RJP" FOR INPUT AS #1
 04A5   02C8            INPUT #1,PATNUM%:        'read number of patterns in dir
 04B7   02C8            GOSUB GETNAME:           'prompt for and input pattern n
                ame
 04BD   02C8            LINE (1,1)-(318,189),0,BF:      'erase graphics tablet
 04E2   02C8
 04E2   02C8            GOSUB SEARCH
 04E8   02C8
 04E8   02C8            IF I% < (PATNUM% + 1) THEN GOTO FOUND
 04FC   02CA            LOCATE 10,16-(LEN(NAME$)/2):PRINT NAME$;" not Found";
 0531   02CE            LOCATE 12,14:PRINT "Strike Any Key"
 054B   02CE            GOSUB ANYKEY:    'wait for a keyhit
 0551   02CE            GOTO FIRST
 0555   02CE
 0555   02CE    FOUND:
 055A   02CE            FILE$ = RIGHT$(STR$(I%),LEN(STR$(I%))-1) + "PAT.RJP"
 057E   02D2            OPEN FILE$ FOR INPUT AS #1:      'set pattern data file
                for read
 058F   02D2            INPUT #1,ELNUM%:         'read number of elements in pat
                tern
 05A1   02D2            INPUT #1,GRID:           'read grid size
 05B3   02D2            INPUT #1,REPEAT%:        'read repeat count
 05C5   02D2            INPUT #1,XOFF:           'read x axis offset for repeat
 05D7   02D2            INPUT #1,YOFF:           'read y axis offset for repeat
 05E9   02D2
 05E9   02D2            FOR I% = 0 TO ELNUM% - 1
 05F7   02D4                FOR J% = 0 TO 5
 05FD   02D4                    INPUT #1,SCNDAT%(I%,J%):'read file into screen
                array
 0621   02D6                NEXT J%
 0631   02D6            NEXT I%
 0643   02D6            CLOSE #1:        'done with data file
 064A   02D6
 064A   02D6            OPEN "PATDEF.RJP" FOR OUTPUT AS #1
 065C   02D6            PRINT #1,FILE$:                 'save filename in defau
                lt file
 066C   02D6            PRINT #1,NAME$:                 'save the directory nam
                e as well
 067C   02D6            CLOSE #1
 0683   02D6
 0683   02D6            GOTO REDRAW
 0687   02D6
 0687   02D6    SEARCH:
 068C   02D6            I% = 1:                         'set entry pointer
 0693   02D6    SLOOP:
 0698   02D6            LINE INPUT #1,A$:        'read next pattern name from di
                r
 06A5   02D6            IF A$ = NAME$ THEN GOTO SEARCH.END:     'compare name w
                ith dir entry
 06B8   02D6            I% = I% + 1
 06C1   02D6            IF I% < (PATNUM% + 1) THEN GOTO SLOOP:'check for done
 06D4   02D6    SEARCH.END:
```

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Reagent Jet Printer                                              PAGE  6
Pattern Entry/Modification                                       07-05-86
                                                                 10:46:13
Offset  Data    Source Line          IBM Personal Computer BASIC Compiler V2.00

 06D9   02D6          CLOSE #1:         'not found so close file and display me
                ssage
 06E0   02D6          RETURN
 06E4   02D6
 06E4   02D6    REM SPAGE
```

```
Offset  Data    Source Line         IBM Personal Computer BASIC Compiler V2.00

06E4    02D6    PATSAVE:
06E9    02D6            GOSUB ITEMBOXERASE:     'erase blue box around DIR
06EF    02D6            IF ELNUM% = 0 THEN GOTO FIRST:  'no elements in pattern
06FE    02D6            OPEN "PATDIR.RJP" FOR INPUT AS #1
070F    02D6            INPUT #1,PATNUM%
0721    02D6            IF PATNUM% < 80 THEN GOTO SAVE.PAT:     'directory full
         at 80 patterns
0730    02D6            CLOSE #1
0737    02D6            LOCATE 25,1:PRINT SPACE$(39);:          'erase bottom l
        ine
0754    02D6            LOCATE 25,1:PRINT "Directory is full (80 patterns max)"
        ;
076E    02D6            GOSUB ANYKEY:GOTO FIRST
077B    02D6    SAVE.PAT:
077D    02D6            GOSUB GETNAME:  'prompt for and get pattern name
07B3    02D6            GOSUB SEARCH
07B9    02D6            IF I% > PATNUM% THEN GOTO ADD.NEW.PATTERN
079A    02D6            LINE (1,1)-(318,189),0,BF:      'erase graphics tablet
07BF    02D6            LOCATE 10,13-(LEN(NAME$)/2):PRINT NAME$;" already exist
        s.";
07F4    02D6            LOCATE 12,15:PRINT "Replace it?"
080E    02D6            PATNUM% = I%
0815    02D6            A$ = ""
081F    02D6            WHILE A$ = ""
082E    02D6                    A$ = INKEY$
0838    02D6            WEND
083B    02D6            IF A$ = "Y" OR A$ = "y" THEN GOTO SAVE.PATTERN
0864    02D6            GOTO FIRST
0868    02D6
0868    02D6     ADD.NEW.PATTERN:
086D    02D6            KILL "PATDIR.OLD":      'delete old backup directory
0874    02D6            NAME "PATDIR.RJP" AS "PATDIR.OLD":      'save old direc
         tory
087E    02D6            OPEN "PATDIR.OLD" FOR INPUT AS #1
088F    02D6            OPEN "PATDIR.RJP" FOR OUTPUT AS #2:     'set up new dir
08A1    02D6            INPUT #1,PATNUM%:       'read number of dir entries
08B3    02D6            PATNUM% = PATNUM% + 1:  'increase by 1
08BC    02D6            WRITE #2,PATNUM%:       'save in new directory
08CD    02D6            FOR I=1 TO PATNUM% - 1
08E6    02DA                LINE INPUT #1,A$:   'read entry from old dir
08F3    02DA                PRINT #2,A$:        'write entry in new directory
0903    02DA            NEXT I
091E    02DA            PRINT #2,NAME$:         'write new entry to new directo
         ry
092E    02DA            CLOSE #1:CLOSE #2:      'done with directory
093C    02DA     SAVE.PATTERN:
0941    02DA            FILE$ = RIGHT$(STR$(PATNUM%),LEN(STR$(PATNUM%))-1) + "P
         AT.RJP"
0965    02DA            OPEN FILE$ FOR OUTPUT AS #1:    'create new pattern dat
         a file
0977    02DA            WRITE #1,ELNUM%:        'store number of elements
098B    02DA            WRITE #1,GRID:          'store grid dimension
0998    02DA            WRITE #1,REPEAT%:       'store repeat count
09A9    02DA            WRITE #1,XOFF:          'store x axis offset for repeat
```

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Reagent Jet Printer                                                    PAGE   8
Pattern Entry/Modification                                             07-05-86
                                                                       10:46:13
Offset  Data    Source Line          IBM Personal Computer BASIC Compiler V2.00

 09B9   02DA            WRITE #1,YOFF:          'store y axis offset for repeat
 09C9   02DA            FOR I% = 0 TO ELNUM% - 1
 09D7   02DC                FOR J% = 0 TO 5
 09DD   02DC                    WRITE #1,SCNDAT%(I%,J%):        'write screen a
                rray to file
 0A03   02DC                NEXT J%
 0A10   02DC            NEXT I%
 0A22   02DC            CLOSE #1:       'done with data file
 0A29   02DC            OPEN "PATDEF.RJP" FOR OUTPUT AS #1
 0A3B   02DC            PRINT #1,FILE$:                 'save filename in defau
                lt file
 0A4B   02DC            PRINT #1,NAME$:                 'save the directory nam
                e as well
 0A5B   02DC            CLOSE #1
 0A62   02DC            GOTO FIRST
 0A66   02DC    REM $PAGE
```

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Reagent Jet Printer                                              PAGE   9
Pattern Entry/Modification                                        07-05-86
                                                                  10:46:13
Offset  Data    Source Line        IBM Personal Computer BASIC Compiler V2.00

 0A66   02DC    PATDRAW:
 0A6B   02DC            GOSUB ITEMBOIERASE
 0A71   02DC            LINE (1,1)-(318,189),0,BF:     'Erase graphics tablet
 0A96   02DC
 0A96   02DC    NEXTEL:
 0A9B   02DC            MENUNUM = 2
 0AA5   02DC            GOSUB SUBMENU
 0AAB   02DC
 0AAB   02DC            ON ITEM + 1 GOTO ALINE, RECT, SRECT, ACIRCLE, REDRAW, B
                ACKUP
 0ACB   02DC            GOTO NEXTEL
 0ACB   02DC
 0ACB   02DC    BACKUP:
 0AD0   02DC            GOSUB ITEMBOIERASE
 0AD6   02DC            GOTO FIRST
 0ADA   02DC
 0ADA   02DC    ALINE:
 0ADF   02DC            TEMP% = 1
 0AE6   02DE            STARTMSG$ = "STARTING ENDPOINT"
 0AF0   02E2            ENDMSG$ = "ENDING ENDPOINT  "
 0AFA   02E6            GOTO ENTERELEMENT
 0AFE   02E6
 0AFE   02E6    RECT:
 0B03   02E6            TEMP% = 2
 0B0A   02E6            GOTO RECTMSG
 0B0E   02E6
 0B0E   02E6    SRECT:
 0B13   02E6            TEMP% = 3
 0B1A   02E6    RECTMSG:
 0B1F   02E6            STARTMSG$ = "STARTING CORNER"
 0B29   02E6            ENDMSG$ = "ENDING CORNER  "
 0B33   02E6            GOTO ENTERELEMENT
 0B37   02E6
 0B37   02E6    ACIRCLE:
 0B3C   02E6            TEMP% = 4
 0B43   02E6            STARTMSG$ = "CENTER OF CIRCLE"
 0B4D   02E6            ENDMSG$ = "POINT ON CIRCLE "
 0B57   02E6
 0B57   02E6    ENTERELEMENT:
 0B5C   02E6            GOSUB ITEMBOIERASE
 0B62   02E6            FLAG%=0
 0B69   02EB            LOCATE 25,1:PRINT SPACE$(39);
 0B86   02EB            LOCATE 25,1:PRINT STARTMSG$;
 0BA0   02EB            GOSUB DISPCURSOR
 0BA6   02EB    FINDSTART:
 0BAB   02EB            GOSUB MOUSEACT
 0BB1   02EB            IF A$ = CHR$(27) THEN GOTO ABORT
 0BC8   02EB            IF A$ = CHR$(13) THEN GOTO SETSTART
 0BDF   02EB            GOSUB CURSORMOVE
 0BE5   02EB            GOTO FINDSTART
 0BE8   02EB    ABORT:
 0BED   02EB            GOSUB PLACECURSOR
 0BF3   02EB            GOTO NEXTEL
 0BF7   02EB
```

```
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Pattern Entry/Modification                                            07-05-86
                                                                      10:46:13
Offset  Data   Source Line        IBM Personal Computer BASIC Compiler V2.00

 0BF7   02EB   SETSTART:
 0BFC   02EB          LOCATE 25,1:PRINT ENGMSG$;
 0C16   02EB          FLAG% = TEMP%:X1% = X%:Y1% = Y%
 0C2B   02EC          IF FLAG% = 4 THEN PSET (X%+4,Y%+4)
 0C55   02EC   FINDEND:
 0C5A   02EC          GOSUB MOUSEACT
 0C60   02EC          IF A$ = CHR$(27) THEN GOTO CANCELEL
 0C77   02EC          IF A$ = CHR$(13) THEN GOTO SAVEEL
 0C8E   02EC          GOSUB CURSORMOVE
 0C94   02EC          GOTO FINDEND
 0C97   02EC   CANCELEL:
 0C9C   02EC          GOSUB PLACECURSOR
 0CA2   02EC          ON FLAG% GOSUB ER1, ER2, ER3, ER4
 0CB3   02EC          FLAG% = 0
 0CBA   02EC          GOTO NEXTEL
 0CBE   02EC   SAVEEL:
 0CC3   02EC          GOSUB PLACECURSOR
 0CC9   02EC          IF FLAG% = 4 THEN CIRCLE (X1%+4,Y1%+4),SQR((X%-X1%)^2+(
               Y%-Y1%)^2),,,,1
 0D32   02EC          GOSUB CORRECT
 0D38   02EC          IF A$="N" THEN GOTO REDRAW
 0D4B   02EC   STOREEL:
 0D50   02EC          SCNDAT%(ELNUM%,0) = FLAG%
 0D6A   02EC          SCNDAT%(ELNUM%,1) = X1%
 0D85   02EC          SCNDAT%(ELNUM%,2) = Y1%
 0DA0   02EC          SCNDAT%(ELNUM%,3) = X%
 0DBB   02EC          SCNDAT%(ELNUM%,4) = Y%
 0DD6   02EC          SCNDAT%(ELNUM%,5) = 0
 0DEF   02EC          ELNUM% = ELNUM% + 1
 0DF8   02EC          FLAG% = 0
 0DFF   02EC          GOTO NEXTEL
 0E03   02EC   REM $PAGE
```

```
Offset  Data   Source Line        IBM Personal Computer BASIC Compiler V2.00

0E03    02EC   REDRAW:
0E08    02EC            GOSUB ITEMBOXERASE
0E0E    02EC            LINE(1,1)-(318,189),0,BF
0E33    02EC            IF ELNUM% = 0 THEN GOTO NEXTEL
0E42    02EC
0E42    02EC            FOR I=0 TO ELNUM%-1
0E5B    02F0                    ON SCNDAT%(I,0) GOSUB RD1, RD2, RD3, RD4
0E81    02F0            NEXT I
0E9C    02F0            GOTO NEXTEL
0EA0    02F0
0EA0    02F0   '******** Sub-routines called by main module ********
0EA0    02F0
0EA0    02F0   SUBMENU:
0EA5    02F0
0EA5    02F0            LOCATE 25,1:PRINT SPACE$(39);
0EC2    02F0            ON MENUNUM GOSUB MENU1, MENU2
0ED1    02F0
0ED1    02F0            FOR I=0 TO 6
0EDB    02F0                    READ MENU$(I)
0EF2    02F0                    LOCATE 25,(I*6)+2:PRINT MENU$(I);
0F2B    02F0            NEXT I
0F46    02F0
0F46    02F0            READ MAXITEM
0F4D    02F4            ITEM = 0
0F57    02F4
0F57    02F4   NEWITEM:
0F5C    02F4            GOSUB NEWITEMBOX
0F62    02F4
0F62    02F4   NEXTITEM:
0F67    02F4            GOSUB ITEMSEARCH
0F6D    02F4            IF A$ = CHR$(13) THEN RETURN:'  ITEM has correct value
0FB4    02F4            IF LEN(A$) < 2 THEN BEEP:GOTO NEXTITEM
0F9A    02F4            IF ASC(MID$(A$,2,1)) = 75 THEN GOTO LEFTAR
0FB6    02F4            IF ASC(MID$(A$,2,1)) = 77 THEN GOTO RIGHTAR
0FD2    02F4            BEEP:GOTO NEXTITEM
0FD9    02F4
0FD9    02F4   LEFTAR:
0FDE    02F4            IF ITEM = 0 THEN GOTO NEXTITEM
0FEE    02F4            GOSUB ITEMBOXERASE
0FF4    02F4            ITEM = ITEM - 1
1003    02F4            GOTO NEWITEM
1007    02F4
1007    02F4   RIGHTAR:
100C    02F4            IF ITEM = MAXITEM THEN GOTO NEXTITEM
101F    02F4            GOSUB ITEMBOXERASE
1025    02F4            ITEM = ITEM + 1
1034    02F4            GOTO NEWITEM
103B    02F4
103B    02F4   MENU1:
103D    02F4            RESTORE MN1
1044    02F4            RETURN
1048    02F4
1048    02F4   MENU2:
104D    02F4            RESTORE MN2
```